INTRODUCTION TO COMPUTER AIDED DESIGN (CAD) FOR THE HOUSING INDUSTRY

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Alberta
DEPARTMENT OF HOUSING
Innovative Housing Grants Program

INTRODUCTION TO COMPUTER AIDED DESIGN (CAD) FOR THE HOUSING INDUSTRY

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of the Alberta Department of Housing.

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FOREWORD

This study was made possible with funding provided by the Innovative Housing Grants Program of the Alberta Department of Housing. Originally conceived in 1978, the Program is intended to encourage, sponsor, and assist research and development in the fields of housing, site and subdivision design, energy conservation, site servicing and building product development. Generally, the aims of research funded by the Innovative Housing Grants Program are to reduce housing costs, increase the supply of appropriate housing or improve the utility or performance of dwelling units or subdivisions.

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Innovative ideas come from a wide variety of applicants such as builders, developers, consulting firms, industry associations, municipal governments, educational institutions, non-profit groups and individuals. As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied.

Please send comments and suggestions or requests for further information to:

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1.0 INTRODUCTION

The purpose of this report is to provide a basic understanding of Computer Aided Design hardware and software, to assess how it relates to the housing industry and to offer some guidelines on the selection of a CAD system.

It has been stated many times, from many different sources, that there will virtually be no architectural firm in five years time that does not employ some degree of CAD technology. With CAD technology continually getting less expensive and more versatile, it would appear that this trend will affect all the design disciplines.

The housing industry is a heavy user of architectural services and/or the related design and drafting disciplines, and as a result CAD technology will become a significant aspect of the housing industry in the near future.

This report will take a general look at what CAD technology is, what it can do and what the components are. It will then look at how graphic and associated non-graphic information is processed in the housing industry, and how CAD fits into this scenario.

The report will then discuss some of the significant considerations in the acquisition of a CAD system, who the main vendors are, some advice to buyers, and where CAD technology is headed. The appendices include a glossary of terms, a list of CAD hardware, software and turnkey vendors, and lists of publications and recent articles.

2.0 INTRODUCTION TO CAD

2.1 Computer Aided Design

CAD or Computer Aided Design and drafting is the process of bringing a graphic idea to hard copy with the assistance of computer technology.

Just as business computers process numerical data, CAD systems store, retrieve, manipulate, and display graphic information.

The typical CAD system allows the designer to sit at a terminal or work station and interact or communicate with the computer. The work station would have a TV-like display (cathode ray tube - CRT), a typewriter-like keyboard, a graphic input device (mouse, joystick, digitizer), a hard copy device (printer or plotter), and some means of storing information (magnetic tape or disk drive), (See Figure 1).

FIGURE 1 INTERGRAPH DSP 055 INTERACT COLOR WORKSTATION

2.2 The Use of Computer Aided Design Technology

The primary functional purpose of a computer aided design and drafting system is to assist the user in creating design and technical drawings. This is done by taking advantage of the repetitive nature of such drawings, and this is implemented by creating a "library", or "computerized template" of standard graphic symbols that are used over and over again. These library symbols are created on the CAD system only once, and are stored on disk (and/or tape) for use in specific drawings. The symbols may be "primitives" such as lines, arcs, circles, or standard symbols such as doors, stairs, plumbing fixtures, or electrical symbols or user defined macros i.e. user created symbols derived from primatives and stored as a single entity.

By securing a "menu" of symbols to the sensitized work surface (data tablet or digitizing tablet), the user may pick and select the symbol to be used with the electronic pen. Various graphic system commands are used in conjunction with the library of symbols to add, delete, connect, rotate or move these components interactively. The commands may be entered into the system via electronic pen, alphanumeric keyboard, function keyboard or menu (see menu Figure 2 on page 4).

Annotating the drawing is typically done via keyboard. It can also be performed by utilizing off-line text entry techniques or by incorporating standard, often-used notes in the symbol library. The result is a drawing, complete with symbols, notes, dimensions, and component characteristics.

Creating drawings is only one of the functions performed by CAD systems. A substantial part of total system productivity is in the editing or revision function. Since the original drawing file is resident on the disk (or may be retrieved from archival tape storage facilities), it is easy to call up a copy of that file into the active area of the disk for revisions or changes. These revisions are performed in much the same manner as was used in originally creating the drawing. Once done, the revised drawing may be stored as a revision copy, plotted and/or may replace the original drawing file.

INTERGRAPH

TEXT
TX- Text Size
TH- Text Height
TW- Text Width
FT- Font
SN- Active Symbol Font
NN- Node Number
LL- Line Length
LS- Line Spacing
TI- Tag Increment

PRECISION INPUT
XY- Coordinates (Drawing)
DI- Distance & Direction (View)
DL- Delta X,Y,z (Drawing)
DX- Delta X,Y,Z (View)
AX- Auxiliary Coordinates (Absolute)
AD- Delta Auxiliary Coordinates

STREAM DIGITIZE
SD- Delta Distance
ST- Tolerance

CELLS
AC- Active Cell
CM- Cell Matrix
CC- Create Cell
CD- Delete Cell
CR- Rename Cell

ATTRIBUTES
AE- Active Entity
CS- Change Attribute Spec
RA- Review Attributes
DS- Define Search Spec
ON- Define Owner
DR- Display Report
FU- Fall Universe File
DA- Displayable Attr Type
RS- Report Specification
RO- Report Output File

COLOR
CT- Color Table
CO- Color Name/Value

FILES
RD- Retrieve Design
Rn- Reference File (1,2,3)
RC- Retrieve Cell Library
NC- New Cell Library
OX- Retrieve UC Index
NX- New UC Index
DB- Retrieve DMRS Data Base
EL- Generate Element List
AL- Active Element List
FF- File Fence
SF- Separate Fence
XD- Exchange Design (1,2,3)

SCALE
AS- X,Y,Z Scale
XS- X Axis Scale
YS- Y Axis Scale
ZS- Z Axis Scale

TERMINATOR
LT- Terminator Name
TS- Terminator Scale

VIEWS
WO- Window Origin
AZ- Set Active Depth
DZ- Change Active Depth
DP- Set Display Depths
DD- Change Display Depths
VI- Select Named View
RV- Rotate View

PATTERNS
AP- Active Pattern Cell
PA- Active Pattern Angle
PS- Active Pattern Scale
PD- Active Pattern Delta

LEVELS
LV- Active Level
ON- Level On
OF- Level Off
Dn- Display Level (Ref File)
Rn- Level Off (Ref File)

MISC
AT- Activate Tutorial
TV- Dimension Tolerance
LD- Dimension Level
AA- Active Angle
GU- Units Per Grid
GR- Reference Grid
UR- Unit Roundoff
GO- Global Origin
LC- Active Line Style
WT- Active Line Weight
CL- Class Mask
AM- Select Active Menu
UC- Select User Command
PT- Active Point
DF- Down Load Font

POLYGONS: SELECT
PLOTS: REQUEST
DIGITIZER: SETUP

ANGULAR DIMENSIONING: UNITS (LENGTH | DEGREES) | POINT | ARC
DIMENSIONING CONTROL: PLACEMENT (AUTO | MAN) | WITNESS LINES (ON | OFF) | JUSTIFICATION (L | C | R)
RADIAL DIMENSIONING: RADIUS | DIAMETER
LINEAR DIMENSIONING: ACTIVE AXIS | SIZE | LOCATION | LABEL LINE

ACTIVE ENTITY: DEFINE | AUTO ATTACH ON/OFF
REVIEW: SINGLE ELEMENT | REPORT
SET OWNERSHIP: SINGLE ELEMENT | FENCE CONTENTS
SCALE: AS=1 | 1 = 2 | 1 = 3
ACTIVE OWNER: CHANGE (PARENT | CHILD) | CLEAR
DISPLAYABLE ATTR: ATTACH | LOAD (SINGLE | FENCE) | GENERATE
ANGLE: 0 | 90 | 180 | 270

MEASURE: X,Y,(Z) | ΔX, ΔY, (ΔZ) DRAWING | VIEW | 1 DIST TP | 2 ANG TP 1 | AREA DEF | ELEM | AUX COORD
RADIUS | DISTANCE ALONG ELEMENT | ANGLE BETWEEN LINES | PERPENDICULAR TO LINE,ARC | DISTANCE CUM | MIN | AUX DELTA

PATTERNS: LINEAR | SCALED | AREA | REVIEW ATTR | SEGMENT MULTI | SINGLE | DELAY ON/OFF
USER COMMANDS: 1 2 3 4 5 6 7 8 9 10 | 11 12 13 14 15 16 17 18 19 20
ATTRIBUTE MANIPULATION: ATTACH ACTIVE ENTITY (ELEMENT | FENCE) | CHANGE ATTR VALUES (ELEMENT | FENCE) | REMOVE ATTRIBUTES (ELEMENT | FENCE) | DELETE ENTITY ON/OFF | COPY ATTRIBUTES

COMPRESS DESIGN
DESIGN OPTIONS
FILE DESIGN
DISPLAY HEADER

LOCKS: TEXT NODE | AXIS | UNIT | SNAP (OFF | KEYPT | PROJ) | REF FILE SNAP (1 | 2 | 3) | GRID | ANGLE | SCALE | GRAPHIC GROUP | LEVEL | INF LINES | BORE LOCATE | FENCE CONTENTS (ATTR | INSIDE | OVERLAP | CLIP)
RASTER VIEW CONTROL: ZOOM (IN | OUT) | PAN | EXIT | EXIT & SAVE | DRAG ON/OFF | DYNAMIC (AREA | DROP | VOLUME)
AUX COORDINATE SYS: VIEW ALIGN | MOVE

UPDATE: L | R | BOTH | VIEW
STOP DRAWING

FAST DISPLAY ON/OFF: CURVE ARC ELLIPSE | TEXT | FONT | CELL
DISPLAY ON/OFF: WEIGHT | PATTERN | TEXT NODE | ENTER DATA FIELD | LEVEL SYMB | DIMEN DATA | CONST LINES | GRID
VIEW CONTROL: DELAY (L | R) | VIEW ON | VIEW OFF | COPY | SWAP | OVER VIEW ON/OFF | TUTOR VIEW
VIEW SCALE: ALIGN VIEW | ZOOM (IN | OUT) | FIT | WINDOW (AREA | CENTER | VOLUME)
VIEW ROTATION
DEPTH: ACTIVE | DISPLAY

FENCE CONTENTS MANIPULATIONS: MOVE | ROTATE (ORIG | COPY) | COPY | SCALE (ORIG | COPY) | DELETE | MIRROR ORIG (V | H | L) | CHANGE SYMB | MIRROR COPY (V | H | L) | ADD TO WORKING SET (ORIGINAL | COPY)

FENCE: MODIFY | MOVE | RADIUS | MODIFY ANGLE | AXIS
ARC | PARTIAL ELLIPSE | FILLET | PARAB | SPIRAL | ELLIPSE | CIRCLE | LINE | LINE STRING | SHAPE | CURVE (STREAM | SPACE | SMOOTH)
CELL: ACTIVE (REL) | SELECT (REL) | DEFINE ORIGIN | IDENTIFY | REPLACE | PLACE (VI) | FIT (VI) | NODE (VI) | EDIT
TEXT: ABOVE | PLANO | BELOW | ON | HGHT | WIDTH
POINT: ACTIVE POINT

TEXT ATTRIBUTES: DISPLAY | CHANGE
COPY & INCREMENT: TEXT | ENTER DATA

WORKING SET: DROP | ADD TO WORKING SET (ORIGINAL | COPY)
CREATE CHAIN

ELEMENT MANIPULATIONS: COPY | SCALE (ORIG | COPY) | DELETE | CHANGE SYMB | PARTIAL DELETE | SQUARE | PROJECT | SURFACE OF REV | MOVE | ROTATE (ORIG | COPY) | MODIFY | DROP | CLEAR INTER | MIRROR ORIG (V | H | L) | MIRROR COPY (V | H | L)

GRAPHIC GROUP: ADD TO | DROP FROM

TEXT JUSTIFICATION: "XX | XX | XX" | -XX | XX | XX- | .XX | XX | XX.

CONST TAN ARC
ENTER DATA: FILL IN SING | AUTO | COPY | JUSTIFY (L | C | R)

TEXT NODE JUSTIFICATION:
XX "XX XX XX" XX
XX -XX XX XX- XX
XX .XX XX XX. XX

ADJUST TRAVERSE
COPY PARALLEL
EXTEND LINE
CONSTRUCT LINE (TANGENT, PERPENDICULAR)
CONSTRUCT LINE AT AA
CONSTRUCT BISECTOR (ANGLE, LINE)
CONSTRUCT TANGENT CIRCLE
CONSTRUCT LINE BETWEEN ELEMS
CONSTRUCT POINT

INTERGRAPH MENU

FIGURE 2

A third major function of CAD systems is data extraction/processing, i.e. the input, storage, manipulation, and retrieval of non-graphic information. Most CAD systems provide some or all of the following subsidiary data extraction and data processing features:

- bill of materials,
- job accounting record,
- length, area, volume calculations,
- specifications,
- costs, and
- data "overlays", allowing specific graphic information to be put on specific data levels

This is only a partial list of what various CAD systems offer with respect to data extraction and data processing of graphic information. Another point to mention with respect to data base manipulation is the availability of both two and three dimensional data bases. Some CAD systems have the capability of working in a true 3D data base. Designers typically work in two views, and changing the geometry of an object in one view automatically changes it in the other view. Each point in a 3D drawing file has an x,y,z coordinate. In addition, the user may design in any orthogonal view or in the isometric view. Hidden line removal may be done by various semi-automatic or interactive techniques, in which the portions of the drawing to be hidden are removed or changed to dashed line representations.

2.3 CAD In The Workplace

CAD systems come in many configurations and in various sizes. The larger systems are used in very large scale engineering projects such as aircraft design. In such applications, very large volumes of information must be

stored and retrieved. Such a system would involve several terminals communicating with a common central computer system. Such a system is called a Host-satelite CAD system. In some cases, such as the automotive industry, these CAD systems are directly linked to the manufacturing process. They directly control machines and link all other manufacturing functions such as materials handling, inventory control, scheduling, etc.

Smaller CAD systems, based on mini computer technology and containing their own central processing units, are used extensively in the engineering disciplines, and to a lesser extent in the architectural field.

The latest move in CAD technology is personal computer (PC) based CAD. For the purpose of this report micro computers and PC computers will be used interchangeably. This technology involves independent software developed specifically for micro computers, usually the IBM PC and compatible machines, and the Apple II e. Many of the major computer graphics vendors have recognized the significance of this trend and have introduced or are in the process of introducing PC based CAD systems. This technology is developing at such a rapid pace that it would appear that this is the technology most likely to advance into the small design office, and as a result have the greatest impact on the housing industry.

2.4 CAD Tools

The typical stand-alone CAD system includes a CPU (central processing unit), mass information storage (disk and/or tape), a cathode ray tube (CRT), a graphic input device, an alpha numeric keyboard, a function keyboard, and a graphic output device. In addition, the software is the set of computer instructions which completes the typical CAD system.

A typical stand-alone turnkey system is shown in the following illustration:

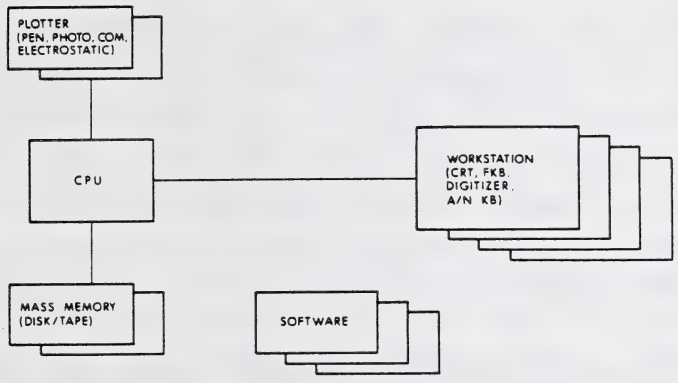


FIGURE 3 TYPICAL STAND-ALONE CAD CONFIGURATION

2.4.1 Software

It has been stated many times by various sources that when selecting a CAD system, choose the software first. Although this is a rather simplistic statement, it emphasizes the importance that should be given to the software.

Software provides the series of computer instructions which activate and control various portions of the CAD hardware. The picture on the face of the monitor is usually formed by implementing a series of software instructions. They position the cursor (the on screen pointing device eg. cross hairs or arrow) and cause lines, characters, and other symbols to be automatically drawn, connected, and modified to create a design. See Section 4.2 for some of the more significant software functions.

Graphics often consist of considerably more than just drawing pictures. Pictures must be manipulated (enlarged, reduced, rotated, etc.) and ultimately used as part of an application process (making charts, mechanical designs, shading, process control, or observing certain results). The software must also activate the various CAD input and output devices.

In larger CAD systems, the software is generally proprietary, i.e. designed and marketed by the CAD vendor specifically for the system that is marketed. In some cases, for example if a system is using VAX CPU technology (DEC, Digital Equipment Corporation trade name), third party software will be available in the market place. It is advisable however, when purchasing a host-satelite system or a mini based CAD system, to select a system for which the software is as complete as possible within the turnkey package.

Micro based CAD software is generally independent software designed to run on a micro computer, particularly the IBM PC, compatibles and derivatives, and the Apple II e or Apple II c. In some cases, hardware modification boards may accompany a software package to increase the speed and functionality of the software.

2.4.2 Hardware

2.4.2.1 Information Processing

The Central Processing Unit

The Central Processing Unit (CPU) is the brain of the computer. It controls the retrieval, decoding, and processing of information, as well as the interpretation of operating instructions. In other words, the CPU contains the electronic logic which actually receives individual instructions, and causes the events specified by the instructions to occur.

Memory

The memory is where the program and data are stored. The CPU is not large enough to store all of the instructions it will have to execute, so these are stored external to it in memory chips. There are two kinds of memory chips, ROM and RAM. ROM stands for "Read Only Memory". Information stored there is non-erasable and can only be read. This is a permanent set of instructions and data. ROM is used as start-up code when the machine is first turned on. Generally, the ROM programming (or code) will allow the CPU to advance to some state in which it is referencing a keyboard in order to find out what the user wants it to do next.

What the user will probably want to do is load and execute some application program. From some outside source, the user will cause that program to be loaded into the, "Random Access Memory" (RAM). This kind of memory can be both read and written. You can put a program in this memory, use it, and then put another program right over it. You can write new information into RAM at will and read it when you need it, just like magnetic tape.

The Graphic Processor

The graphic processor and the graphic monitor determine the quality of the monitor image. The processor translates the data base image in memory for display on the monitor. If either of these devices has poor resolution (see Section 4.3.1 for description of graphic resolution), the image is less clear. This is a significant consideration when purchasing a micro computer based CAD system.

2.4.2.2 Information Storage

The random access memory typically available on a computer, is not large enough to store the quantity of information generally required in a data file. There are special devices that can store large data files with ease. This data can be transferred to and from the computer memory as required.

A computer can store data files on tape (cassette or reel to reel), floppy disks, or hard disk units. They all store information on a magnetic surface, much as tape cassette players record music on the magnetic surface of a tape cassette. Each type of magnetic surface must be mounted in a special drive unit that contains mechanisms required to read information off the magnetic surface or write information onto it.

Tape cassettes are adequate only for small microcomputer systems handling simple functions. For intermediate functions, use diskettes. Complex functions can use more sophisticated diskette drives with large data storage capacity, or they use hard disks.

Tapes

Some big computers store information on large reels of magnetic tape, but magnetic tape units are used in microcomputer systems only to back up hard disks.

Floppy Disks

A floppy disk is a disk made of materials similar to magnetic tape. Floppy disks come in three sizes: 8 inch, 5 1/4 inch and 3 1/4 inch diameter. The diskette spins inside a disk drive, and a moving arm precisely positions a read and write head at any point on the diskette surface that needs to be accessed. Therefore, any part of the diskette surface can be accessed

accurately and immediately; you can write on the diskette without fear of damaging previously written information.

Diskettes are inserted into diskette drives. Diskettes hold a moderate amount of information. The least expensive disk drives store approximately 160,000 to 180,000 characters (bytes) of information on a single diskette. The most expensive drives store well over one million characters (bytes) of information on a single diskette.

By computer standards, it takes a long time to write information onto a diskette, or read information from it. It can take up to two seconds to find a particular spot on a diskette surface and then read information from that spot, or write information to that spot. This may not seem like a lot of time, but it becomes significant when the disk is accessed many times throughout the drawing process.

Hard Disks

If a floppy disk does not hold enough information for your operations, or it accesses information too slowly, a hard disk should be considered. This is a solid metal disk with magnetic coatings on one or both surfaces. Information is written on this magnetic surface in much the same way as it is written on a floppy disk. From five million characters (bytes) to over one hundred fifty million characters of information can be stored on a hard disk. The hard disk is mounted in a disk drive which spins it at very high speed. This allows any location on the disk surface to be accessed in thousandths of a second. Characters can be written onto the disk, or read from it, at rates of approximately one million characters (bytes) a second.

Hard disks are mounted in two types of disk drives:

1) Removable cartridge disk drives.
2) Winchester disk drives.

Removable cartridge disk drives, as the name implies, house the hard disk in a special cartridge container which can be removed from the disk drive. Therefore, you can store a lot of information on different cartridge disks, just as you can on different floppy disks or cassette tapes.

Winchester disk drives, on the other hand, have a rigid disk permanently sealed inside the drive. Therefore, the rigid disk can never be removed. The capacity of the one sealed rigid disk is all you get and may be anywhere from 5 to 150 megabytes. But Winchester disk drives are less expensive than removable cartridge disk drives.

2.4.2.3 The Terminal

The terminal consists of graphic input devices, an alphanumeric keyboard, a function keyboard, and usually a digitizing surface. The feedback mechanism that shows the operator what is happening is a graphic display terminal or cathode ray tube (CRT).

Data Input

There are two primary steps to data input: cursor movement, and command or data entry. The cursor indicates the point on the graphic display at which the next operation is to occur and the command or data entry indicates what is to take place at that point. The cursor may be indicated by cross hairs, an arrow, or a small "x" on the monitor.

These input functions may all be done through the use of the alphanumeric keyboard, or may involve the use of a number of different input devices in various configurations.

The Keyboard

The alphanumeric keyboard is a work station device consisting of a typewriter-like keyboard which allows the designer to communicate with the system using English-like command language. It contains letters, digits, and special commands which are machine-processable. While most CAD systems would allow all graphic commands to be carried out on the keyboard, most systems allow for other input devices to perform commands as it is generally faster and requires fewer operations.

Cursor Movement

The cursor is a crosshair or pointer which appears on the graphic display terminal and is used to indicate the location at which a graphic operation is to occur, or are used for data entry in systems which have an on screen menu (locations on the screen which denote the function to be performed).

There are various devices to facilitate the cursor movement on the screen. The mouse is a device which, when rolled across a flat surface, duplicates the movement along that surface onto the display screen. Track balls and joysticks generate horizontal and vertical movements of the cursor on the screen. Data tablets transmit the location of an electronic pen when pressed on the tablet surface. Touch pens and light pens enter data points directly onto the display screens, but can be very tiring because they require the operator to hold his hand in the air for extended periods of time.

Data Entry

Once the operator has pointed to a location on the display, the computer must then be told what to do with that point. Commands can be typed into the alphanumeric keyboard, but this tends to be a very slow operation. There are various hardware devices available which allow the operation to perform a single function or series of commands in a one step operation. These devices are generally based in some form on the use of a menu, located on a digitizing tablet or on the screen which when activated, instructs the computer to perform a certain function.

The digitizing tablet is an electronically sensitized surface comprising a rectangular grid of lines which produces signals to the computer according to the position of the stylus pen placed upon it. In addition to its use with the menu, it is used to convert graphic information from existing drawings into digital signals so that the co-ordinates can be input to the computer or displayed on the monitor.

There are various approaches to data entry and when a choice exists, personal preference is a significant factor.

Menus may be on screen or on a digitizing tablet or both, or may be combined with a function keyboard which is independent of the alphanumeric keyboard and individual keys are programmed for specific graphic functions.

2.4.2.4 Graphic Display Terminals

There are three principal types of graphic display used in CAD today. They are storage tube, refresh and raster display.

Storage Tube

The storage tube retains an image continuously for a considerable period of time without redrawing (refreshing). The image will not flicker regardless of how much information is displayed. However, the display tends to be slow relative to raster, the display is monochromatic, and no single element by itself can be modified or deleted without redrawing.

Refresh or Vector Refresh

The technology involves frequent redrawing of an image displayed on a CRT to keep it bright, crisp, and clear. Refresh permits a high degree of movement in the displayed image, as well as high resolution. Selective erase or editing is possible at anytime without erasing and repainting the entire image. Although substantial amounts of high speed memory are required, large, complex images may flicker.

Raster Display

Raster scan is the dominant technology in CAD graphic displays. Similar to conventional television, it involves a line by line sweep across the CRT surface to generate an image. Raster scan features include: good brightness, accuracy, selective erase, dynamic motion capabilities, and the opportunity for unlimited color. The device displays a large amount of information without flicker, although resolution is not as good as with storage tube displays.

Text Monitor

Some CAD systems have separate raster displays for monitoring text functions. The advantage of this approach is that the graphic display is kept clear of non-graphic information.

2.4.2.5 Graphic Output Devices

Data Output

In a CAD system, plotters and displays properly complement each other. A display is capable of rapidly presenting a relatively low-accuracy picture so that the user can react to it, perhaps making changes as required before making a hard copy. A plotter, on the other hand, can generally make large, highly accurate drawings but more slowly. Typically, displays are used to make the initial decisions, and plotters to make the record copies.

Drum Plotters

The earliest and perhaps most widely used type of plotter is the drum plotter (See Figure 4). Plot paper is wrapped around the drum and the drum rotated by a digital stepping motor. The rotation provides one deflection axis while the pen, mounted on a gantry across the drum, provides the other deflection axis. The only other basic control besides X and Y deflection, associated with pen plotters is the control to move the pen up and down.

FIGURE 4 DRUM PLOTTER

Flatbed Plotters

Unlike the drum plotter where the rotation of the drum provides pen movement along one axis and the lateral movement of the pen provides movement along the other axis, flat-bed plotters hold the paper or drawing surface flat, using a vacuum system in larger tables, and the pen or pens are moved over the paper (See Figure 5).

FIGURE 5 FLATBED PLOTTER

Electrostatic Plotters

While it takes seconds (or even fractions of a second) to display an image on the cathode ray tube, the time required to plot that same drawing on a precision plotter may take tens of minutes.

In an effort to reduce plotting time at the expense of some drawing quality, electrostatic plotters were introduced. Essentially, these plotters consist of a combination of wire nibs (styli) spaced from 100 to 200 styli per inch. As in the drum plotter, the paper's motion provides one axis of deflection. Instead of a pen moving along the other axis, however, the information is progressively "scanned" across the styli, and those styli needed to place a dot on the paper are activated (See Figure 6).

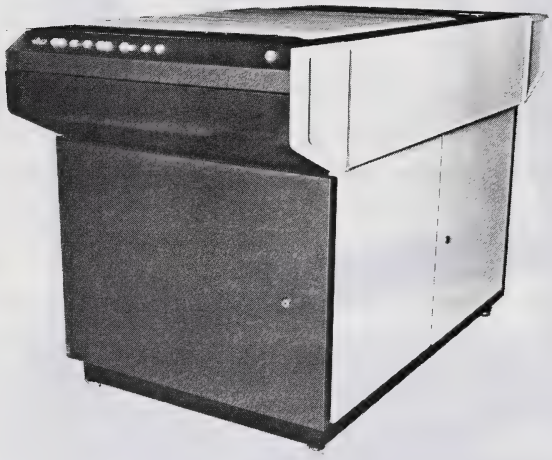


FIGURE 6 ELECTROSTATIC PLOTTER

Photo Output Devices

There are a number of photographic devices which either produce a slide, negative, or print directly from the CRT or transfer a digital signal to film. Although these systems produce a non scalar image which could not easily be used for construction, they do produce very good quality presentation graphics (See Figure 7).

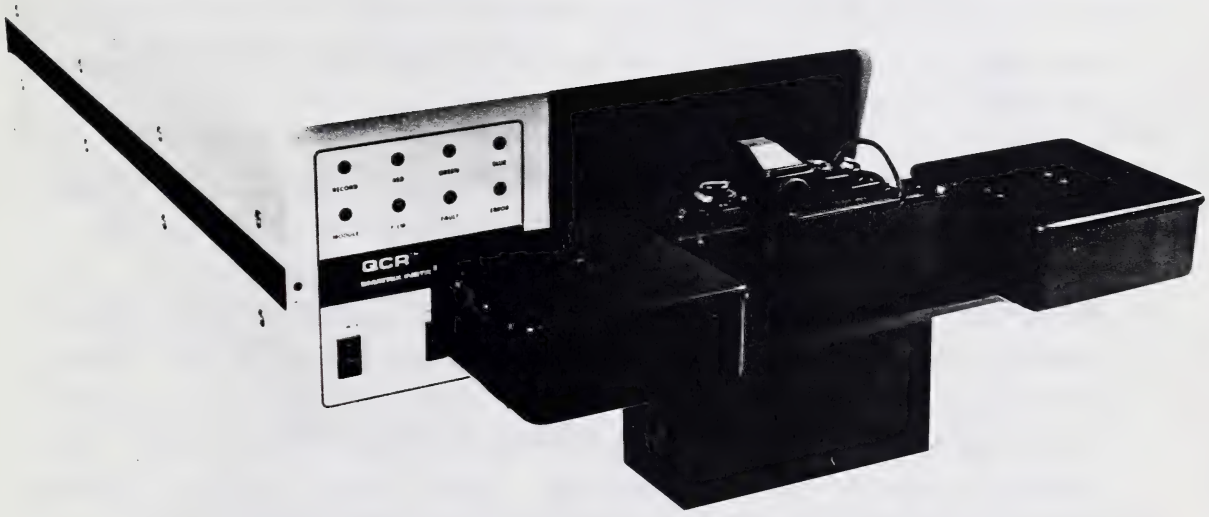


FIGURE 7 PHOTO OUTPUT DEVICE

2.5 Marketing CAD Systems

CAD technology is available in many configurations to meet a very broad range of uses in the CAD/CAM, and CAE fields. (Computer-Aided Design/ Computer-Aided Manufacturing, Computer-Aided Engineering). The three main

classifications of CAD systems were at one time based on the storage capacity of the computer, and the speed with which information is processed, and could be classified as main frame based, mini based, and micro based systems. However, the technology is developing at a very rapid pace and the power of various systems has increased dramatically. It is very difficult to establish a division between various systems using this method of classification. A much more workable system of classification is host-satelite systems, stand alone turnkey systems, and personal computer software.

2.5.1 Host-Satelite Systems

Host-satelite systems involve the use of a large scale digital computer connected to a number of graphic work stations.

Such systems can store hundreds of drawings and may involve dozens of work stations plugged into a network of CPU's. Host-satelite systems are used in the aero space industry, large scale engineering mega projects, the automotive industry, and in CAD/CAM operations (Computer Aided Design/ Computer Aided Manufacturing). The technical capabilities of such systems generally exceed the needs of the housing industry, and most large computer vendors have designed stand alone CAD systems which will run the same software as the host-satelite systems. These smaller systems have the capability of networking in the same fashion as the larger systems. For these reasons, host-satelite based CAD will not be discussed further in this report.

2.5.2 Stand-Alone Turnkey Systems

Technological developments in CAD have put the computer power once reserved for the host-satelite CAD systems into stand alone workstations. Thus, the middle range in CAD technology has become the stand alone turnkey system, i.e. hardware plus applications specific software.

The more sophisticated of these systems will be full color high resolution, and will perform various high level engineering functions and sophisticated graphics display functions. The lower end systems may be no more than a two dimensional drafting system.

The CAD/CAM, CAE product varies considerably in this range of computer graphics and the rate at which the technology develops is very dynamic. The larger companies with the more sophisticated products generally tend to put more money back into research and development. As a result some vendors introduce hardware and software advances on a quarterly basis, whereas others may take a year or more. However, there are always enough innovations occurring on the open market to make positioning of the vendors in the marketplace very volatile.

Stand alone systems may have enough processing power to act as a host computer for additional terminals or may act as an intelligent work station networked with several other stand alone systems through a large CPU.

Stand alone turnkey systems are therefore very flexible in their size and configuration.

2.5.3 Personal Computer Software

Personal computers, like other sectors of computer technology are advancing at a very rapid pace. The first PC CAD system appeared on the market about 3 1/2 years ago and now there are over twenty software packages on the market.

As PC based CAD entered the market place, the PC vendors, and in particular IBM have developed hardware innovations geared specifically to the micro CAD market. These modifications include faster processors, hard disk storage, and high resolution graphic displays.

There are presently more than 20 companies offering CAD systems based on micro computers. Revenues of this fast-growing segment, which covers micro-based systems for engineering and architectural drafting, solids modelling and electronic circuit analysis and layout, are projected to reach $40 million in North America in 1984 (Daratech newsletter 9/28/84).

AutoCAD is the fastest selling PC-based CAD software package for engineering, mechanical and architectural drafting and may capture 25 percent of the PC-based CAD market in 1984.

Because of the market impact that PC based CAD is making, many of the stand alone turnkey vendors have brought out PC based systems. Computervision is marketing an IBM XT which they call Personal Designer and using software developed by 4D Graphics Ltd. of Renton, Washington.

Intergraph has introducted their own Interpro 32 workstation. This is a full 32 bit machine which will run IBM PC software, Unix Software, or can act as a terminal to an Intergraph system (See Figure 8).

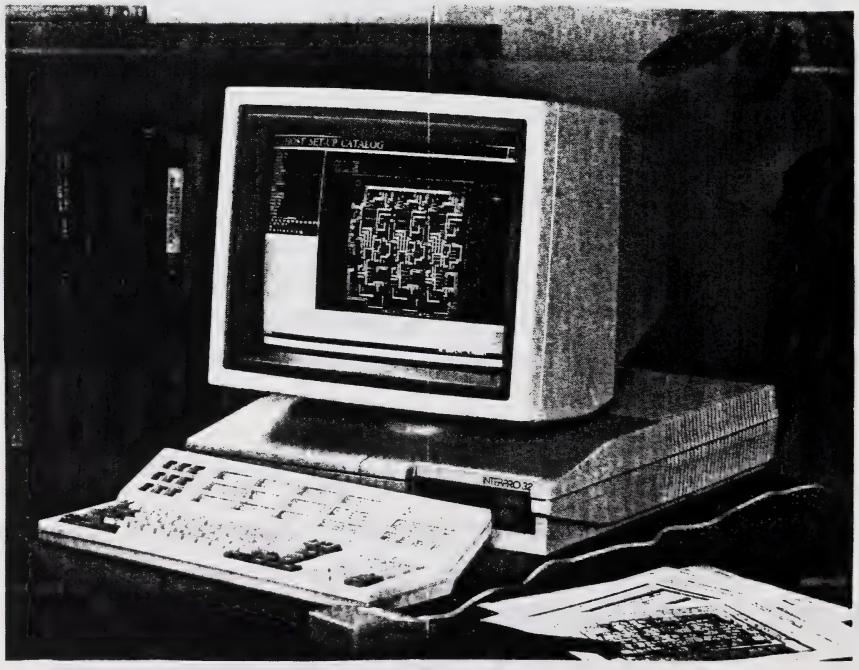


FIGURE 8 INTERGRAPH INTERPRO 32 WORKSTATION

IBM has introducted the 3270 PC and 3270 PC GX line of graphics workstations which will run IBM PC software, their own graphics software, or will act as a terminal or network through their large mainframe computers (See Figure 9).

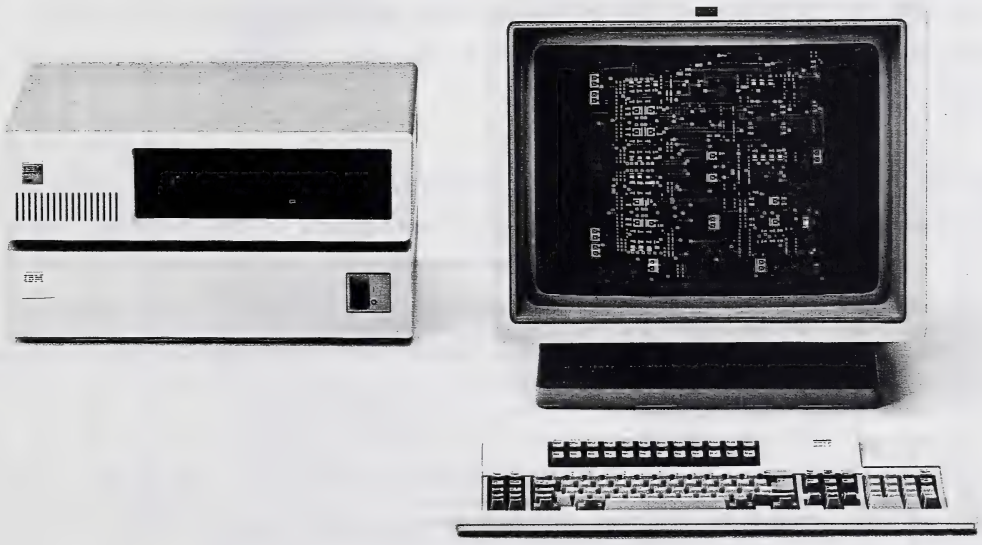


FIGURE 9 IBM 3270 PC GX WORKSTATION

Just as the PC hardware continues to develop, the software is getting more and more sophisticated. There are software packages which will perform such functions as solids modelling, structural analysis, solar design and perspective with hidden line removal.

3.0 THE ROLL OF CAD IN THE HOUSING INDUSTRY

3.1 Introduction

The development of residential land and the subsequent design, construction, and marketing of single family homes is a long involved process which can take up to five years. During this time span a great deal of graphic and non graphic information is processed and many people are involved in this process including developers, planners, builders, design professionals, and home buyers.

It is in the area of accumulation, storage, manipulation, and retrievals of information that CAD will find a significant place in the housing industry.

The following chart indicates the home building process, the scope of work of the various participants, and the relationship of the CAD to the housing industry (See Figure 10).

This section will indicate the various steps involved in bringing housing to the market, identifying the various people involved in those steps, and indicating how CAD technology fits into the overall process.

3.2 Land Development

3.2.1 The Housing Industry Today

The first participant involved in bringing a house to market, and more specifically, bringing a residential lot to the marketplace is the land developer.

The initial stage involves first of all an assessment of a property to determine economic viability. The assessment involves such considerations as: yield per acre based on terrain, drainage, soils conditions, land use planning, costs per developable acre, market conditions, servicing costs, product mix, bylaw considerations, and off-site levies.

Figure 10 indicates the various steps involved in bringing housing to the marketplace, identifies the people involved, and indicates what computer software relates to the specific tasks involved.

KEY ACTOR					ROLE OF CAD						
DEVELOPER	BUILDER	DESIGN PROFESSIONAL	HOME BUYER		2D DRAFTING	3D MODELLING	SITE PLANNING--MAPPING	TERRAIN MODELLING	BILL OF MATERIALS	SPECIFICATIONS	SOLAR DESIGN
				LAND DEVELOPMENT							
/				Property Assessment	/		/	/			
/				Mapping			/				
/				Design	/	/	/				
/				Terrain Modelling		/		/			
/				Technical Drawing	/	/	/	/			
/				Servicing	/		/	/	/	/	
				DESIGN & MARKETING							
	/			Market Analysis							
	/	/		Site Analysis	/	/	/	/			/
	/	/		Solar Design		/					/
	/	/	/	Design Presentation	/	/		/			
	/	/		Preliminary Costing							
	/	/		Marketing	/	/		/			
				TECHNICAL DRAWINGS							
		/		Working Drawings	/	/	/		/	/	/
		/		Specifications						/	
		/	/	Materials Take-Off & Costing					/		
				CONSTRUCTION MANAGEMENT							
	/			Scheduling					/		
	/			Inventory Control					/		
	/			Cost Control					/		

FIGURE 10 THE BUILDING PROCESS AND CAD

Although methods have been developed to make such assessments, they are not particularly accurate, and there is a great deal of experience and guesswork involved in the decision making process.

3.2.2 CAD and Land Development

Through the use of CAD much of the guesswork can be reduced. As the graphic information is being accumulated and processed it can automatically be related to a previously developed information data base. The rules developed from previous experience can become an active part of the CAD package and can set up the appropriate standards for dealing with the information.

Mapping and Terrain Modelling

The CAD graphics function which has the greatest significance to the land development stage of the housing industry is mapping.

Although a simple 2D drafting package would produce the necessary site drawings, there are many advantages to a software package specifically developed for mapping.

There have been a number of systems developed which take data collected from various sources, i.e. original aerial or land surveys, existing maps and documentation, and existing computerized mapping data bases, to produce an integrated digital map.

At this point, such features as automatic dimensioning and area calculations can be very helpful for both the design concept development, and the detailed mapping.

Other very useful features at the detailed design stage are the development of graphic libraries, with associated non graphic information. For example, sidewalks and curb details could be drawn from a library, the dimensions

placed automatically, and such details as length of sidewalk and curb, number and size of curb cuts, cost per linear metre of sidewalk, can all be stored in and retrieved from the data base for materials take-off and cost estimating.

Similarly, site services can be drawn from a library of standard symbols, and such things as sizes, length of run, and accumulated loads and volumes can be determined automatically, and stored in the data base for future use.

Another very helpful CAD program for land development is digital terrain modelling. Terrain modelling software creates a three dimensional model of a site which can not only be used to derive the typical contour plan, but the terraine can be shaped, and cut and fill calculations will be done automatically.

This feature is particularly useful in the large developments done today which involve a great deal of site contouring and use low spots on the site for storm water drainage ponds.

Mapping functions can be carried out very efficiently and effectively with the use of CAD, but the added dimension of linking the graphic and non graphic information into a comprehensive data base makes it a very powerful tool.

The information can now be transferred to the next stage of work, the development of individual lots.

3.3 Design and Marketing

3.3.1 The Housing Industry Today

The design and presentation stages also relate to the marketing stage. Whether it involves the design professional presenting a drawing to a client or the home builder presenting designs to a prospective home buyer, the ultimate goal is to sell an idea.

The tools generally used for this purpose are design drawings, outline specifications, and preliminary cost information. The presentation drawings would generally include site plan, floor plans and elevations, all drawn to scale, and a perspective.

When the design professional is working with an individual client, there is likely to be a considerable number of design modifications before coming up with the final design. As the housing market becomes more competitive, the home builder is also finding that the home buyer is demanding a larger degree of design flexibility.

There are two other presentation tools commonly used in the housing industry. They are scale models and show homes. The scale model is used to help the home buyer to visualize a house in three dimensions, and is more commonly used by the design professional than by the builder. The show home is used by the builder to demonstrate the quality of his work, and to create a prominent exposure to the home buyer.

3.3.2 The Role of CAD in Design and Presentation Drawings

Drafting

Strictly as a drafting tool in the design stage, the major advantages of CAD technology are speed and accuracy, the flexibility to make changes quickly, the ability to store each design or design modification for future use, the ability to integrate pieces of various designs into new variations, and the ability to store non graphic information in conjunction with the graphic information.

Design Modification

The great advantage to CAD technology in making changes, is the way in which information is stored. The ability to revise drawings without destroying the original, the ability to move, delete, and alter graphic information easily, and the ability to combine graphic information from data bases, all make the process of design and modification an easier task compared to the old design process. The added design process advantage of having the bill of materials automatically altered becomes a very valuable tool throughout all aspects of compiling the graphic and non-graphic information.

Three Dimensional Presentation Graphics

Three dimensional computer graphics offer an even greater degree of flexibility for presentation graphics. Some CAD systems have the capability to produce a house design in perspective which can be viewed from any angle, interior or exterior, and shaded to reflect sun angles at anytime of day or year. Finishes can be shown and colors can be changed throughout a palet of over 4,000 colors. The house designs can be furnished or landscaped and be placed on a chosen site, and the site terrain modified as required. Design modifications can be made and viewed instantly.

Computer graphics may very well provide a superior form of presentation compared to the presentation drawings presently used as a marketing aid. The ability to visually walk around or to walk through a house and to select a hard copy from any angle could become a very strong marketing tool.

Three dimensional graphic modelling has another major use in conjunction with the design process. That is in the field of solar design. The ability to shade a three dimensional image from any light source angle, allows the design to be studied for the purpose of shading and solar gain. For example, the relationship of a window to a trombe wall could be studied to derive the maximum solar gain at specific times of the year.

Text Requirements

Supplemental to the design drawings, there is a considerable amount of non-graphic information which the home builder requires at the design and marketing stage. This information would include outline specifications, floor areas, general design descriptions, design and material options and costs.

Scale Model and Show Home

There is some question as to whether or not the home buyer would accept computer graphics as a substitute for the show home, but the flexibility which exists in viewing a three dimensional computer graphic image at the very least would become a very valuable supplemental marketing aid to the show home.

As a replacement for a scale model, CAD offers the advantages of dynamic rotations to simulate walking around a house, and the ability to move inside a 3D model.

3.4 Technical Drawings

3.4.1 The Housing Industry Today

The technical drawing and accompanying non graphic information are tools used by the home builder to construct a house. The drawings would include a site plan, floor plans, elevations, building sections, and construction details. The associated non graphic information would include specifications and door and window schedules.

Working Drawings

The main graphics tool in the technical stage is the working drawings. Working drawings are the graphic representation of the house to be built, and are used as the basis from which to construct the building, and to develop accurate construction costs.

Site Drawings

At the technical stage, detailed information on the actual building site is required. This information would involve a site plan with dimensions, elevations, locations of services, sidewalks, curbs, and possibly existing trees and shrubs.

Design Modifications

Just as in the design and presentation stage, the design professional and the home builder must be prepared to make changes to the technical information package. This requires that the working drawings be changed and specifications, bill of materials, and costs be altered to reflect the changes.

Specifications

Specifications serve the dual purpose of setting a standard for materials used and workmanship for the builder and the subtrades and for guaranteeing the home buyer that the house that he buys meets a certain standard.

Energy Management

It may be required on occasion to present various energy conservation alternatives to the home buyer. Such things as changing insulation values, and glazing alternatives will not only affect energy consumption, but will also affect the final price. It is then the responsibility of the builder to determine the energy cost and construction cost implication for the home purchaser. A decision to make changes would alter the working drawings, bill of materials, specifications and those changes may affect the scheduling and inventory control.

3.4.2 CAD At The Technical Drawing Stage

CAD may be looked upon as a drafting aid for creating a set of architectural drawings, and in fact, some of the small CAD systems are little more than just that. However, if CAD is used as a system which catalogues and organizes both graphic and non graphic information it can be a very powerful tool.

In essence, the graphics and associated non-graphic information required in the housing industry is a homogenious body of knowledge in which a change in any one information component can affect all the other components. CAD technology applied to this body of information becomes an information management system. It provides a continuity by establishing a direct relationship between the graphic and non-graphic information.

The way that this unity is provided by CAD technology is that as each graphic element is created, it can be assigned non-graphic information at the same time. For example when a door frame is drawn it is not just a series of lines which represents a door frame, it is a graphic element which represents a door frame and it also has certain other properties assigned to it such as three dimensional size, materials, finish and color. It can also have other assigned properties such as heat loss values, cost, manufacturer, and installation instruction, etc. In this way, the graphic information becomes directly linked to all the non-graphic information required to derive any function or relationship.

The data file can be supplemented or manipulated throughout all stages of a project to provide the information appropriate to that stage of work.

Working Drawings

The link between graphic and non-graphic information is a significant advantage of CAD technology at the working drawing stage.

The other major advantage of CAD which can not be overlooked is its efficiency as a drafting tool. Although productivity increase of up to 12 to 1 have been claimed for CAD, a more realistic ratio of from 1.5 to 1 to 3.5 to 1 is an accepted figure in the architectural field. The reason that CAD technology is so efficient is that it greatly simplifies the drawing process. Very simple methods are used for creating lines, arcs, circles, and ellipse in real scale. These graphic elements can be combined in two dimensional space or three dimensional space to create the desired image. Three dimensional graphic systems allow for the creation of surfaces such as planes, spheres, cylinders, and cones.

Dimensioning and lettering are also very simple procedures and the ability to store graphic elements in a data base for repeated use greatly reduces the time lost to drawing the same element over and over again. The ability to use the design drawings and base sheets for the working drawings further increases productivity. See Section 4.2 on page 38 for discussion of "layers".

Site Drawings

Assuming that CAD has been used for the land development stage of the work, the information provided for the technical drawing stage can be very comprehensive, and will not require any redrawing.

Design Modifications

The ease with which design modifications can be made with CAD is probably the most significant reason for increased productivity ratios. A design can be called up to be changed, and a copy made to be stored as an original, and the revised design would become a new model.

If the system has bills of materials and specification software, the changes can also be reflected in the non-graphic information data base.

Specifications

As discussed earlier, non-graphic information can be assigned to the graphic information. In this way, with some CAD systems, specifications can be directly linked to the drawings with the use of a specifications software program. Once an element is drawn and defined, the appropriate section will be pulled from the specifications software, and upon command, will be printed out in the specifications.

Energy Management

By linking the graphic and non-graphic information into a common data base, the implications of design changes can be reviewed instantly. In this way, changes in insulation values or exterior wall thickness or window type or size can all be checked for cost implications in terms of energy consumption and construction costs.

The bill of materials could be set up to separate out exterior walls so that various construction alternatives can be compared.

The use of shaded images as a solar design tool can be used throughout the technical stage and design alternatives could be compared in terms of cost and pay-back.

3.5 Construction Management

3.5.1 The Housing Industry Today

Once the technical information package is complete, it will not only be used to construct a house, but it is used by the builder as the basis for costing, scheduling and inventory control.

Costing

Costs and cost control originate from the materials take-off. By adding a labour component to the costs of materials, a price is derived. As design changes are made, the costs must also be altered to reflect design modifications. Once the price has been established, scheduling and inventory control become significant factors in controlling costs and cash flow.

Scheduling and Inventory Control

In scheduling a project, the builder must be able to relate the availability of trades and materials, the time allotted to various construction stages, the cash flow, and seasonal climatic conditions. Inventory control involves having the materials for each stage of construction on site as they are needed, but not holding the materials unduely long before they are needed. The two major factors which make inventory control a significant factor in home building are that money can be tied up in the purchase of materials longer than necessary, and materials stored on a jobsite are open to theft and vandalism.

Scheduling and inventory control are both directly related to the bill of materials. Quantities of materials must be known in order to initiate the scheduling and inventory control.

3.5.2 CAD and Construction Management

The reason that CAD can become a valuable asset in the construction management phase of a housing project, is the capability of generating a bill of materials from the data file.

Costing

The bill of materials is an accurate breakdown of the types and quantities of building materials and components. By associating unit costs and labour factors to the bill of materials, detailed construction costs can be derived.

Any design changes are immediately reflected in the bill of materials, and these changes or changes in unit costs or labour costs will instantly be reflected in the final construction costs.

Scheduling and Inventory Control

Through the use of CAD the builder would be able to separate out various stages of work from the working drawings and generate a separate bill of materials for each stage. Materials would then be ordered according to each stage of work being done. Although this is generally the way the builder controls his inventory anyway, the advantage of the CAD system is that the take-off can be done very quickly, design or cost changes could be reflected instantly and these are extremely accurate.

4.0 CAD EVALUATION

This section will address some of the more significant considerations in the assessment of current CAD systems. Operating systems, software functions, and hardware will be discussed in reference to the present state of CAD technology.

4.1 Operating Systems

An operating system is software which controls the execution of computer programs and the flow of data to and from peripheral devices. It is also the interface between any particular software program and the hardware, it dictates what software can be read by what hardware, and it is used as a management system for disk files.

The operating system is dependent upon the microprocessor being used. For example the IBM AT personal computer uses an INTEL 80286 microprocessor and will run IBM PC DOS 3.0 software or IBM PC XENIX software, the IBM equivalent of the UNIX operating system.

The Intergraph Interpro 32 has a National Semiconductor Series 32000 CPU for Intergraph and Unix-based programs, and an Intel 80186 processor for input/output processing and for IBM MS/DOS software.

Xenix and Unix are comparable and apparently compatible, and may become an industry standard for micro based CAD. It is too early to tell if Xenix and Unix will overtake MS/DOS, the IBM-PC operating system.

4.2 Software Features to Look For

On-line Status

On-screen status items, such as layer number (explained later), grid status, type of line, the cursor's x-y coordinate position, and various interactive prompts, are helpful. The ability to get information about your drawing or entities (geometric primitives) within it is also helpful. For example, if you want to know the size of your coordinate system, the exact location of a particular item, or the default status of various program parameters, the on-line status feature give you access to this information.

Menus

It can be very cumbersome and frustrating to select program functions from the alphanumeric keyboard. Command menus that you point to on the screen or on a digitizing surface are a desirable feature. The best menu approach appears to be the use of a digitizing tablet on which is placed a menu card. The symbol or command to be used can then be chosen by touching the appropriate area of the menu card with an electronic pen. In addition, if you have the freedom to design your own menu, you can develop a custom application using only those selections that apply to your drawing needs.

Macros and Command Files

Macros and command files are groups of program instructions and other data-entry items that can be executed with a single keyboard entry. For example, if it takes five steps to merge a disk file into a current drawing the necessary instructions can be placed in a macro/command file and executed with a single command. These macros can even be placed as selections on the menu.

Further custom flexibility exists if the software lets you stop during macro execution and issue a prompt for data entry. For example, the user can develop a menu item that creates a shape; goes to a particular location; enters text mode; sets the font size, and direction; and prompts the user to enter the test string. The more powerful the macro capability, the more custom applications can be developed.

Grid

A CAD software package should allow the operator to set up grid points that serve as reference points while creating a drawing. Look for the ability to specify the distance between grid points and to choose a different scale for the x and y axes. The grid points should not become part of the database or appear on the printer or the plotter.

When grid lock or grid snap is activated another desirable feature is that the data points you enter "snap" to the nearest grid point no matter where they are entered. This permits a degree of error when entering data points. This is especially helpful when trying to align different drawing layers, close irregular shapes, or enter data points quickly and accurately.

The ability to vary the distance between grid points becomes important with grid lock/snap. It allows the user to change the coarseness of the drawing resolution as it is fine-tuned. For example, it is possible to zoom in on one square centimeter, snap to the nearest millimetre for detail drawing, then zoom back out, snapping to the nearest centimeter.

With the incremental snap feature the cursor stops only on grid points or resolution points as it moves across the screen.

Aspect Ratio

The program should correct for the aspect ratio of the display devices. Aspect ratio is a design engineering term that refers to the ratio of display width to height. For example, a monitor with a resolution of 320 by 200 pixels presents a circle as an ellipse and a square as a rectangle unless the software makes the right adjustments. This is quite important if proportion matters during data entry or when using the display for a final presentation.

Data Entry

Shapes, blocks, groups, components, and dictionary items are all different names for similar drawing elements. The system should allow the user to create drawing elements, store them in a symbol library, and merge them into a current drawing, rescaling and rotating them as desired. The ability to automate repetitive drawing tasks is one of the more important features of a CAD program. For example, if an architect wants to merge one of a variety of drainage systems into a foundation/site plan, he can retrieve the right one from a drawing library on file rather than redraw it from scratch.

Keyboard Entry

The ability to enter data from both a keyboard and an optional input device is desirable. Positioning the cursor, entering relative or absolute coordinates, and keying formulas that result in appropriate curves are all important.

Drawing "Primitives"

The availability of "primitives" (lines, arcs, circles, rectangles, etc.) are important considerations in a particular program. The number of ways to define an object are also important. For example, a circle may be defined as a center and radius, two points determining a diameter or three points on the circumference.

There are many other primitive capabilities. They include cross-hatching or filling an area (with or without user-definable patterns), fillets (automatically turning an angular corner into a rounder corner) and built-in math calculations.

The primitive features available in CAD software vary widely. The more flexibility to customize the primitives, the more versatile and effective the software is.

Automatic Dimensioning

Automatic dimensioning is a very significant CAD function. It should suit the needs of a user.

Any architectural drawing may have a number of different types of dimensions. Along with conventional rectilinear dimensioning, a drawing may require angular and radial dimensions. There should also be some flexibility in the placement of the dimension line and the numbers, and automatic changes from metric to imperial.

Layers

If the CAD software provides multiple layers, the drawing ability is augmented. Layers are like pieces of tracing paper stacked one on top of the other that you apply individually for display and hard-copy output. For example, when designing a house, a site can be developed on layer one, a foundation plan on layer two, a floor plan on layer three, an electrical plan on layer four, a plumbing plan on layer five and a roof plan on layer six. This enables the user to see the overall house with all its details integrated and to have the freedom to see and draw each individual plan independently. If all layers are turned off except the electrical plan, that plan can be sent to a hard-copy device. If the floor plan layer is turned on, the electrical drawing can conveniently be worked on against the appropriate background.

"Rubber banding"

"Rubber banding" helps in trying to conceptualize the drawing process by allowing the operator to view alternatives for the placement of a line on the screen before it is actually entered. The line stretches like a rubber band while pulling it to the next data point.

Editing Features

The ease and power of the editing capability are important considerations with CAD software. The user must be able to manipulate the images created while rescaling, rotating, and moving them around. This allows for easy correction of mistakes and modification of drawings.

If, in the example of the house plan, a previously completed drawing of a house is a completely different scale from the site plan, the ability to load the old house plan and merge it with the new site plan while rescaling it and rotating it for proper sun exposure would be extremely helpful.

Partial Delete

A feature quite often absent in lower-priced CAD systems is the ability to delete part of a previously drawn image without having to erase and reconstruct the whole thing. For example, to break a house wall and put in a window, the number of entities and data points is changed and the database updated. This feature, which is quite important in editing drawings, allows tremendous flexibility. Without it work must be preplanned resulting in a rigid drawing lacking in spontaneity.

Windowing

This is the process of defining an area to be manipulated by setting up two opposite corners of a rectangle that contains it. For example, an area can be windowed in order to delete, move, copy, save, or zoom in on it. With the rubber-banding feature, the window can be dynamically expanded and contracted once one corner is defined. This allows the operator to view window placement alternatives before making a decision as to the exact placement.

Zoom and Pan

The ability to move an image across a screen (pan) and to visually move in and out (zoom) from the image is a very desirable feature in a CAD system. This enables the operator to enlarge a drawing and move to a specific area for detailed work, and then to move back in the drawing to view the area just worked on in relationship to the whole drawing.

Bill of Materials

Not all micro CAD software packages nor even turnkey CAD systems have a bill of materials feature built into the CAD software. The bill of materials develops a cumulative inventory of building components in the computer data base. This list can then not only be used for materials take-offs and costing, but for door and window schedules, inventory control, and scheduling.

Tutorial and Help Functions

User friendliness is a term used to qualify the ease with which a CAD operator can learn and use a CAD system. CAD systems are generally becoming more user friendly, but vendors have also adopted various approaches to make their systems easier to use. These range from on line help functions and tutorial software, to video tape tutorials and written manuals. A prospective purchaser should review this aspect of a vendor's product.

4.3 Hardware

Processors

The advent of the Motorola 68000 microprocessor has been responsible for a major technological breakthrough in micro-based CAD systems.

The 68000 is responsible for 32 bit technology becoming an industry standard in minicomputer base CAD and is rapidly entering the domain of micro-based CAD. A byte is a set of binary digits (bits) operated on as a unit by a computer. Computers are either 8 bits, 16 bits, or 32 bits per byte.

The power of a 32-bit computer is illustrated by comparing it to 8-bit and 16-bit computers - a bit being the number of digits of information a computer can handle at one time. An 8-bit computer can deal with 256 items at a time, such as the names of all the workers in a company with 256 employees. A 16-bit computer can address 65,536 items of information, such as the names of all the residents of a small city. A 32-bit computer can address more than four billion items of information. 32-bit technology is considerably more powerful than 8- or 16-bit in that information can be accessed much more quickly, and considerably more information can be stored.

While 8-bit architecture allows addressing only 64 K bytes of RAM, 16 bit processors can typically address a full megabyte.

All 16-bit systems may not be comprehensive 16-bit systems. Because of restrictions of both design and economics, some 16-bit microprocessors are used in conjunction with an 8-line data bus. The processor itself manipulates 16-bit words within, but these words are "doubled up" across an 8-line data bus after they leave the processor. This is called multiplexed buses (the Intel 8088 is used in this capacity); the combination will slow down operations compared to a comprehensive 16-bit system (referred to as a 16/16 system). In reality, an 8-bit data bus, with a 16-bit processor (an 8/16 system) may have only a marginal execution speed advantage over a standard comprehensive 8-bit system. But this will vary with different applications and with many hardware and software factors associated with computer design and performance.

Undoubtedly, the most important consideration is the availability of software. Applications software usually is designed for specific operating systems, and operating systems are designed to be used only with specific processors. Eight-bit systems have been on the market for some time and extensive software exist for their operating systems. Errors have been worked out and the software has proven practical through long periods of in-use trial and error.

Some systems are originally designed with co-existing 8- and 16-bit processors. Various techniques exist for running 8-bit software on 16-bit machines but they vary in efficiency and reliability. Using software designed for an 8-bit processor on 16-bit systems often underutilizes the rich instruction set and large addressing capabilities of the 16-bit architecture.

The processors used in microcomputers fall into a number of general categories:

1. Atari, Apple family and other computers with proprietary operating systems use the 6502 microprocessor chip. Accelerator boards provide 8088 and 68000 chips for some of these.

2. S-100, Multibus, and other systems like the Victor 9000 use the Z80 or 8086, 8087 and/or 8088 microprocessors.

3. IBM PC XT and the growing number of PC look-alikes use the 8086/8088 microprocessor and optionally the 8087 numerical data coprocessor.

4. The Motorola 68000 microprocessor is used in Apple Macintosh and Lisa.

5. Intel 80286 and 80287 are used in the IBM PC AT.

RAM

Each CAD software package will specify the minimum hardware requirements. This is seldom below 128 K and more commonly will be 256 K or 512 K (see 2.4.2.1 memory).

Graphic Resolution

The concept of resolution is important to a good understanding of current and future trends in computer-aided design. The number of dots or picture elements used to represent an image determines its resolution. Consider drawing a straight line. Take a pencil and begin placing dots in a line from left to right on a piece of paper. Make the dots about 1/4 inch apart. You are creating a low-resolution representation of a straight line. The finer your pencil point and the more dots you place within the line, the higher the resolution of your drawing is. If you place enough dots along the line, it appears to be a solid line. The same concept applies to circles, solids, text, and other shapes.

In general, the higher the resolution, the smoother and more accurate the image. Obviously, you want the highest resolution possible.

The graphic resolution of the display is designated by the number of pixels (picture elements or dots on the screen) horizontally and vertically. The more pixels that have to be addressed, the more powerful the system has to be.

CRT graphic resolution may be as low as 256 X 256 and as high as 1280 x 1024, and there are systems about to be released with resolution of 2000 x 2000.

The standard monitors for Apple and IBM PC's should be considered the minimum acceptable standard for graphic resolution (640 x 200 pixels). High resolution monitors for micro computers are in the range of 720 x 540 resolution.

Most mini computers have a graphic resolution of 1024 x 1024 or 1280 x 1024.

Monochrome or Colour

The more complex the drawing, the more useful the colour display. Different layers can be displayed in different colors to make the graphic images more readable.

In a system capable of producing both high resolution graphics and color display, color capabilities are usually greater (more colors) in the low-or medium-resolution display modes of the given system. This is because when additional attributes for color are assigned to each pixel, more memory also must be allotted to each pixel, trading off color palette for resolution.

Cascade has introduced shades of grey to distinguish various elements on its monochrome display. It is not as readable as a color display, but it is certainly an improvement over a straight monochrome display system.

Input Devices

Although you can use the keyboard as a primary input device, a specialized device is much easier and more efficient to use.

With manual drafting methods and a conventional drawing board, you physically draw a line from one point to another. You do the same thing with a digitizer or digitizing tablet (electronic drawing board), but rather than use a pencil or pen you use a hand-held cursor device which moves the cursor or crosshairs on the graphic display terminal. You can trace a library of drawing parts you have created over the years for use in assembling your current drawings. You can also work with drawings created manually. Touch pens and light pens enter data points directly onto the

monitor screen - if you do not mind holding your hand in the air - but they do not trace manually created drawings.

Similar to digitizing tablets, but without the expense or the accuracy, a mouse keeps your hand in a restful position on a table or grid plate. Track balls, which use a revolving ball like some video games, video-camera input, and even joysticks are available as graphic input devices. It is a good idea to combine the keyboard, functions keys, and an input device determined by the design work you do. Look for software that supports a variety of input devices in case your preferences change.

Although input devices are a matter of preference, the easiest to use and the most accurate is the digitizing tablet and menu, or the function keyboard and roll ball or joystick for cursor movement.

Output Devices

The least expensive output device for large drawing is a drum plotter. Cal-comp has just introduced an E-size multi-pen plotter for around $8,000. This is considerably less than any equivalent Hewlett-Packard plotter. The difficulty with drum plotters is that they are very slow. A very complex drawing may take an hour to plot on a drum plotter, and can be produced on an electrostatic plotter in minutes. The major trade-off is cost.

There are a number of small color electrostatic plotters that may be suitable for presentation work and are quite inexpensive.

Photo output devices are not suitable for technical drawings because the image is non-scalar, but for presentation they can be very effective. There are photo output devices which will give 4000 x 4000 resolution on a 35 millimetre slide. That is a very sharp image.

Information Storage

Section 2.4.2.2 describes the alternatives for information storage. The most common and cost effective mass storage upgrade for microcomputers is a 10 MB Winchester hard disk.

5.0 THE CAD DECISION

5.1 Buying a System

There is no one accepted method for selecting a CAD system. Because micro-based CAD systems are easier to cost justify than the larger systems the selection process can be less complex, but the ultimate goal is to choose the best system possible for the money available.

Following is an article based on a paper published in 1980 Engineering Conference Proceedings, a Tappi Press publication.* It is a summary of a one year program to choose a CAD system for the Process Control Department of Simons-Eastern Co. of Atlanta Georgia. Although they were purchasing a large CAD system, the process was very thorough, and the questions asked of users and vendors, the benchmark process, and the bid evaluation all have a degree of relationship to any CAD purchase.

In the latter part of 1978, our company undertook an internal audit of engineering procedures to determine the potential for increased automation in the production of engineering documents. The audit, prepared by outside consultants in the field of computer aided design (CAD), revealed a potential for increased productivity, improved production quality, and design cost savings through the use of computer-based design and drafting systems.

Task force approach

A joint task force, composed of members of the materials handling, pump and paper, steam and power, civil-structural, and instrument and electrical departments set out to become familiar with the types of computer-based systems then on the market and the trends and advances expected within the coming years. A feeling for the future was especially important, as the task force was aware that the vendor selected would serve for a number of years to come.

Preliminary visits were made to several users of CAD equipment, and to several vendor home offices. These visits broadened the horizons of the task force, and placed them in a better position to assist in company planning. Additional visits were made by company officers, and by February of 1979 a tentative plan of action had been developed.

Narrowing the Field

By April 1979, the field had been narrowed to nine vendors, and the stage was set for some rapid cutting. Briefings (of 1-hr duration) were held by the task force for each vendor, advising them of what the plans were and what the task force would like to accomplish. These were followed by private showings and many hours of private discussions. The task force then met to review its findings and to record the opinions of each member. There seemed to be general agreement on which system would be the most fun to use, but also recognition that further studies would be required to establish the proper system from an investment point of view. In the final analysis, the bidders list was reduced to five.

User Visits

Recognizing the long-range implications of selecting the proper vendor, the task force moved ahead on all five vendors. Members of the task force were assigned the job of visiting with users of each, and results were compiled on a standard interview form. Key among the questions asked were:

- How long has the system been in service?
- What types of drawings are made on the system?
- How many hours a day does the system run?
- What group has responsibility for the system?
- How were operators selected for the system?

- How is time scheduled on the system?
- How many terminals do you have?
- What types of plotters do you have?
- How much memory does the system have?
- How much information is lost on a power failure?
- Can development and production work be done concurrently?
- Is the software easy to use?
- Does the system have software packages for individual disciplines?
- Does the system have three-dimensional data handling capability?
- What is the response time after requesting a drawing?
- What is the response time for a graphic command?
- What is the computation time for preparing a plot?
- What is the actual plotting time for a complex drawing?
- What is the reliability and up-time of the system?
- What is the response time to a maintenance call?
- What are the qualifications of the service people you deal with?
- Would you buy from this vendor again?

Use of the questionnaire enabled members of the task force to function in a non-emotional environment. Buying a CAD system is a great deal of fun, and it is difficult to lay aside emotions and get down to facts. The questionnaire proved an effective vehicle for a rational assembling of data.

Vendor Reviews

Concurrent with the user visits, and as a part of the same set of travel plans, members of the task force visited each of the five vendor home offices. As with the user visits, a questionnaire approach was used:

- How long has the system been on the market?
- How many facilities is it installed in?
- What type of markets are you now serving?
- What are your plans for future development?

- How large is your service organization?
- How large is your sales organization?
- How large is your engineering organization?
- How long have your company officers been with you?
- Are there mergers, acquisitions, or legal problems on the horizon?

As the questions indicate, the goal in the vendor reviews was to establish the strengths and weaknesses of the corporations behind the equipment. The answers varied considerably and had a significant effect on the final vendor selection.

Formal Inquiry

While the task force was on the road conducting user visits and vendor reviews, the technical specification for the CAD system was being prepared for inquiry. Comprising 2 volumes and some 135 pages, the inquiry contained the following parts:

- Instructions to bidders (mailing addresses, etc.)
- Schedule of prices (to be filled in by bidder)
- Bidder response form (yes/no/remarks columns corresponding to each paragraph of the technical specification)
- Purchase order terms and conditions (FOB point, etc.)
- Benchmark evaluation (summary of performance tests to be required)
- Technical specifications (14 sections; see Table I).
- Appendices (typical applications and drawings)

The heart of the document was the technical specification, the contents of which are given in Table I. The authors of the specification knew - and the vendors soon realized - that the specification asked for many things which were not yet on the market. The reason was that we intended to secure not only the best available technology but also an agreement with the most capable vendor to obtain the best of his advances over the years. The extent to which the bidders were able to meet or discuss specific paragraphs of the specification indicated the extent of their research and development activities.

TABLE 1 CONTENTS OF TECHNICAL SPECIFICATION FOR COMPUTER AIDED DESIGN SYSTEM

Bid Evaluation

A basis for bid evaluation was agreed upon before the first proposal was received, so as to avoid any bias from the proposals of the "favorite" bidders. "Musts" and "wants" were established for several items, with "musts" being judged on a yes/no basis and "wants" on a 1 to 10 scale, weighted as indicated:

Musts

- Efficient production of drawings
- Availability of layering technology
- Use of hybrid or refresh tube
- Communication between Atlanta and Vancouver

Wants

- Hardware - overall evaluation (10)
- Software - functional requirements (10)
- Software - operating system (10)
- Software - application programs (8)
- System warranty (6)
- System support (8)
- Corporate stability (8)
- Maintenance (8)
- Training (8)
- Cost and delivery (6)
- System stability (10)

Cost and delivery scores were based on a detailed comparison of the proposals. Other items in the evaluation were somewhat more subjective and were established in conference sessions after several task force members had reviewed assigned portions of the proposal. System

stability was not on the original bid evaluation, but after the benchmark evaluation it became apparent that it was a critical factor and should be included.

Benchmark Evaluation

During the time that the bidders were preparing their proposals, the task force was preparing a performance test, known in the CAD industry as the "benchmark evaluation". This is a two-to-three-day test, generally conducted at the vendor's home office, simulating the preparation of drawings done by the user. The key is that the user in this instance is the purchaser. If the test simulates the preparation of someone else's drawings, or becomes another "sales meeting", it is a waste of time and will yield little new information.

The test prepared by our company was 3 days in length and was given to all of the serious contenders. It contained two parts, the first being a letter (some nine pages long) describing the tests in sufficient detail to allow the vendor to set up his equipment, select the personnel who would perform the tests, and load into his system any drawings which were to be put in ahead of time. Accompanying the letter were drawings which were similar to those actually brought to the test.

The second part of the test procedure was an expanded version of the first, describing in detail the steps to be taken during the test and the basis on which performance would be judged. This expanded version was given to each vendor on the morning of the test, along with the drawings (suitably marked) required during the test.

A summary of the benchmark evaluation is as follows:

- Set up a drawing with borders, title, file number, etc. Demonstrate libraries, layers, and accounting.
- Prepare a simple schematic. Demonstrate libraries, mirroring, and data extraction. Check paint and plot time.
- Create a multilayered file for drawings of several disciplines. Revise as requested.
- Check 3-dimensional capabilities.
- Check isometric capabilities.
- Check response under saturation conditions.
- Investigate backup procedures, interface with Service Bureaus, and remote data entry.

Final evaluation

The results of the user visits, home office reviews, proposal evaluations, and benchmark evaluations enabled the task force to select both the final vendor and the final system configuration within days after the conclusion of the tests. A verbal authorization was given to the successful vendor, a purchase order was drafted, and plans were laid for room construction, manager training, operator training, system checkout and acceptance, system checkout and acceptance, system library generation, and all of the many other items required for a successful startup. By the time the system arrived in November 1979, the task force had been working together for a year and had a good understanding of the requirements for a successful CAD operation. Operators were working at the terminals 2 days after the system arrived, and production drawings were coming off the system 6 weeks after startup.

Based on a paper published in 1980, "Engineering Conference Proceedings", a TAPPI PRESS publication.

Benchmarks

The benchmark procedure is much simpler when selecting a micro based CAD system, but is every bit as important. The following benchmark was devised by Gary S. Goldman, B.S., Ph.D. of Cascade Graphics Development, to test the performance of micro based CAD systems. The productivity ratios below were also provided by Gary S. Goldman.

Benchmarks are performance tests which traditionally take place in data processing environments. In this scenario, time comparisons are made for two different machines performing the same functions.

In CAD environments, benchmarks are less revealing since computer graphics involves a human-machine interface. Even if identical drawings are used for benchmarks, a control test is difficult to achieve due to differences in an operator's

(a) learning curve,
(b) ability to effectively use available commands,
(c) prior CAD experience,
(d) exposure to the specific type of drawing,
(e) familiarity with the drawing symbols,
(f) initial preparation of symbol libraries, and
(g) established techniques for production prior to generating the drawing, as well as other factors.

More important, however, is an evaluation of the CAD software, the ease of use, documentation, support, and maintenance. Usually, the more comprehensive the CAD software, the greater the productivity potential - regardless of the claimed "horsepower".

Productivity is the single greatest concern to many prospective CAD buyers - and rightly so. Productivity, which is measured as the ratio of computer to manual drafting times, typically ranges from 1:1 for unique mechanical details and non-repetitive architectural drawings, to 10:1 or more for such basic drawings as electrical ladder diagrams, typically generated by making minor modifications to similar existing networks. Productivity ratios of 2:1 and 3:1 are commonly recognized for mechanical and architectural drawings that share similar repeated symbols; ratios of 4:1 and higher are reported for electrical, electronic schematics, flow diagrams, P&IDs and

other non-scaled drawings. Drawings that are regularly revised often yield much higher CAD-to-manual ratios.

The above mentioned productivity ratios are generally achieved using sophisticated, high-speed, minicomputer based systems. Most micro-based systems fall short in response times - especially as the drawing becomes dense or filled with many graphic objects. A state-of-the-art micro-based system will, however, display performance and response times comparable to those achieved by the more sophisticated minicomputers. Performing the quick benchmarks given below will reveal whether or not response times are representative of state-of-the-art design:

Create 400 circles, each 0.2" in diameter, assembled in 20 rows and 20 columns with 0.5" spacing between adjacent circle centers. Record and compare the times to accomplish each of the following activities:

Benchmark Activity	Time
Save the entire drawing to disk	5.0 seconds
Zoom-in to a 5" x 5" window of the matrix	1.5 seconds
Display a full view of the entire drawing	1.5 seconds
Rotate the entire matrix of 400 circles about its center an angle of 11.5 degrees	3.0 seconds
Unnest the rotated matrix of circles, then move one of the circles to confirm operation.	2.0 seconds

In a networked configuration, state-of-the-art micro-based systems which achieve these performance levels are now being marketed for roughly $20,000 U.S. per workstation.

5.2 Who Are The Main Players?

Until recently the major CAD/CAM, CAE vendors would likely not have been considered for the housing CAD market. However, as CAD technology has become more sophisticated and less expensive the positioning and the direction of the market leaders has ramifications throughout the industry. The following information on the top ten CAD/CAM CAE vendors was taken from a Daratech news release dated September 28, 1984.

The CAD/CAM, CAE industry is on its way to a record breaking year in 1984. With revenues projected to reach $2.8 billion, the annual growth rate has reached 52 percent - up from 40 percent in 1983, and 28 percent in 1982.

This growth has been fueled by the introduction in late 1983, of a generation of more powerful, cost-effective CAD/CAM, CAE systems by each of the five market leaders.

Meanwhile, as some of the major vendors, including Computervision, IBM and Intergraph enter the PC based CAD market, and establish low-cost distribution channels, personal computer based systems should further boost industry growth and put CAD/CAM, CAE tools within reach of all engineers and architects and other designers.

Computervision

Computervision is a world leader in the CAD/CAM, CAE industry with an overall 20 percent market share.

It introduced a new-generation of 32 bit computers in September, 1983 and since then has introduced a steady stream of new hardware and software announcements, including the IBM PC XT based Personal Designer.

In a break with previous policies, Computervision will base new-generation products on purchased computer and workstation hardware, and concentrate its hardware R & D and manufacturing resources on optimizing performance and special-purpose hardware accelerations. In the software area, Computervision will continue to develop key graphics and applications packages in-house, but will look to outside vendors for specialty applications packages and operating software.

IBM

According to a Daratech news release IBM is expected to increase its overall market share to a little over 18 percent for 1984, and to overtake Computervision for the CAD/DAM, CAE market in 1985.

Although the Model 5080 graphics terminals are proving to be superior products from the standpoint of price and performance, the Fastdraft low-cost drafting system that supports up to two workstations, has not sold well. The system which is marketed by IBM and by Ozalid Corporation is priced at just under $100,000 U.S., for two workstations - not a particularly good buy in today's market.* Furthermore, Fastdraft uses outdated vector refresh displays and is relatively slow in performance.* According to industry sources, IBM has recognized the problems and may either upgrade Fastdraft or cut prices to make these systems more attractive.

IBM continues to aggressively build its CAD/CAM, CAE product line with a steady stream of new products. This, together with the 15.3 percent price cuts on Model 4331 and Model 4361 computers announced in September make IBM a strong challenger for the number one spot in the CAD/CAM, CAE industry in 1985.

* according to a Daratech news release

Intergraph

Intergraph - the number three CAD/CAM, CAE company after Computervision and IBM - increased its revenues by more than 77 percent in the first six months of 1984 compared to the same period last year, and continues to increase market share faster than any other company in the industry. Intergraph may reach a 17 percent market share in 1984, almost three points more than last year.

In a departure from its previous practice of basing its system exclusively on Digital Equipment Corporation's general-purpose computers, Intergraph (Digital's best OEM customer) announced a new engineering workstation incorporating National Semiconductor Corporation's 32032 microprocessor. Called Interpro 32, the new $20,000 U.S. workstation can operate as a 32-bit, general-purpose computer that runs third-party software under the UNIX 4.2bsd operating system, or as an IBM-compatible personal computer running programs under MS-DOS. Interpro 32 can also function as a workstation on existing Intergraph also announced Micro II, a Digital MicroVAX II-based, four-workstation system priced between $40,000 and $60,000, which is expected to be ready for shipment in May 1985.

Calma

Calma Company, General Electric's CAD/CAM, CAE subsidiary, previously strong in the traditional electronics CAD/CAM applications area, has let the electronics side of its business slide while emphasizing mechanical and manufacturing applications.*

Calma's sales are expected to grow by more than 40 percent in 1984, a growth that will give Calma almost 9 percent of the market.

The company's outstanding success is due in part to its unique ability to correctly anticipate market needs, then turn these needs into deliverable, cost-effective products and consistently bring them to market at the right time.

* according to a Daratech news release

McAuto

McAuto (McDonnell Douglas Automation Company) moved past Applicon to become the fifth largest CAD/CAM, CAE vendor in 1984. Holding its own against strong competition by IBM and Computervision, McAuto's sales are projected to increase 49 percent giving the company an almost 4 percent overall market share. In the mechanical and manufacturing segment, the area in which McAuto is strongest, the company trails IBM, Computervision, and Calma with 6 percent of the market.

Sales of McAuto's CAD systems for architectural applications are also growing rapidly. With revenues of $10 million in 1984, McAuto's sales in this segment of the market increased more than 108 percent over the year before.

Applicon

Applicon - the Schlumberger Limited subsidiary that only four years ago was the number three CAD/CAM company behind Computervision and Calma - but its position in the market appears to be falling. If current trends continue, Applicon may report the first annual revenue decline in its 15-year history at a time when the CAD/CAM industry as a whole is expected to grow by more than 52 percent.

Failure to fully update its product line is probably the major reason for the company's recent decline.* Applicon does not yet have a system based on a 32-bit computer. In the fast-growing architectural, civil engineering and construction (A-E-C) applications area, Applicon's recent marketing efforts appear to have been mainly in support of its mechanical and manufacturing product lines. Thus, at a time when the A-E-C market is growing at 57 percent per year, Applicon's A-E-C sales emphasis has dropped from about 20 percent of revenues in 1980 to 10 percent of revenues in 1983.

* according to a Daratech news release

Control Data

Control Data is fighting to gain more recognition in CAD/CAM, CAE markets. Having focused much of its turnkey system and service-related activities in the CIM (computer integrated manufacturing), division in November 1983 Control Data continues to build its sales force and extend its product line.

In the services end of the company's business, traditional timeshare revenues are declining because of the proliferation of personal computers and more powerful general-purpose engineering workstations, but certain specialized segments of timesharing, such as large-scale engineering analysis revenues, appear to be growing.

Control Data's strategy is to act as a systems integrator, offering a combination of systems and timeshare services that bring together multiple engineering and manufacturing functions.

Auto-trol

After three years of losses and two years of declining revenues, Auto-trol has made a remarkable comeback. In the first six months of 1984 the company recorded revenues of $33 million, almost 53 percent more than in the corresponding period the year before. At the same time profits were $2 millon, compared with a loss of almost $5 million in the first six months of 1983.

Auto-trol's success is principally due to the acceptance by the market of its Apollo-based AGW workstation products, and a lot of marketing hustle reminiscent of its glory days before 1980. Indeed, Daratech estimates that 1984 revenues will top $70 million, enough for a 3 percent share of the overall market.

In a move designed to expand the company's product offering beyond engineering and architectural design/drafting, Auto-trol has begun to introduce analytical software packages that give its product line a CAE dimension. Typical of these is STEEL-3D, a package for the interactive design and analysis of steel frame structures, and PLAN, a drafting package for the creation and analysis of architectural floor plans.

The CAD/CAM, CAE market is by no means limited to the top ten vendors, but they have the financial strength and the momentum in the marketplace to establish the trends which everyone else will follow. Information on a number of other CAD/CAM, CAE and software vendors appears in Appendix 2 of this document.

6.0 CAD TRENDS

6.1 Mini Based CAD Systems

Section 5.2 identifies to a large extent the direction the mini based CAD vendors are taking in the development of their various products.

Another emerging development in CAD is the current effort to network mini-computers to be more competitive with large mainframe systems. Small stand alone systems are beginning to be linked together to create stand alone networks that can be connected, via telecommunications, to large mainframe computers in order to access data-bases and other application software.

Until recently, networking has been complicated by the fact that turnkey systems supplied by various vendors are non-compatible. Many vendors are now integrating IGES (Initial Graphics Exchange Specification) into their systems. IGES allows for the exchange of CAD drawings between otherwise non-compatible systems.

A few hardware developments taking place include touch and speech input, the rasterization of both input and output devices, the proliferation of 32-bit processors, and the increasing use of color for all aspects for CAD systems.

In terms of software there is a trend in CAD towards the more traditional hardware companies developing joint marketing and support relationships with CAD software systems. IBM's relationship with and support of Lockheed's CADM (Computer Graphics Augmented Design and Manufacturing) software and Dassault Systems' CATIA (Computer Graphics-Aided Three-dimensional Interactive Application) packages are examples of this trend. Also supporting this are GE's purchase of 48% of Structural Dynamics Research Corp., a major vendor of CAD software, and Prime's support of MEDUSA.

Other trends include: the emergence of third-party software vendors, more applications and turnkey systems being developed for very specialized applications, and a movement towards the integration of CAD with other types of software such as word processing, management graphics & project control.

6.2 Micro or PC Based CAD

There are a number of interesting trends developing in the micro based CAD marketplace. Perhaps foremost among them is the entry of micro-based systems into the turnkey marketplace. At present, there are over 30 suppliers of micro-based systems costing under $100,000 that support most of the functions contained in mini-and maxi-based systems.

Some micro-based suppliers are offering three-dimensional geometric modeling capabilities and color raster scan workstations. Most of the micro systems currently support one or two users and have very limited applications. However, it is a very competitive market, and the technology is developing very rapidly particularly in the areas of 32 bit technology and very inexpensive mass storage.

One of the more interesting developments in the area of micro computers is the development cartridge memory or E disk (the E is for emulated). The E disks are software packages often accompanied by a RAM expansion board. Because it is an electronic device with no moving parts it is up to 50 times faster than a floppy disk.

Micro based CAD software is continuing to try to meet the graphic capabilities of the mini based systems. The new developments in PC hardware are helping considerably to meet these goals but presently the software is lagging behind the hardware.

The PC software industry is in the midst of a major restructuring. Some of the reasons for this are outlined below:

1. Because of the proliferation of software packages being developed today it is considerably more expensive and difficult to reach the marketplace. It is estimated that the number of software companies in the U.S. was reduced by more than half by 1985.

2. IBM and AT&T have made major commitments to personal computer software publishing. Although initial reviews of IBM's business software have been mixed, there is little doubt throughout the industry that the programs represent just the first step in IBM becoming a major factor in the software market.

3. There is some concern that IBM may change the open system architecture to a proprietary operating system. This could reduce the opportunities for third party software companies in the MS-DOS compatible software sector.

The CAD decision is complicated by the rate at which technology is developing and by how those developments are brought to the marketplace and by whom. Although no vendor is immune from making mistakes, any development by IBM, DEC, or Intergraph or any of the other major CAD vendors has significant impact throughout the industry. The CAD decision is not a simple one.

APPENDIX 1

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Application Program (or package). A computer program or collection of programs to perform a task or tasks specific to a particular user's need or class of needs. For example, there are mechanical, electrical, architectural, space planning, construction applications, etc.

Automated Drafting System. A computer-based system designed primarily to automate the process of drafting. Design capabilities are not included.

Automatic Dimensioning. A CAD capability that computes the dimensions in a displayed design, or in a designated section, and automatically places dimensions, dimensional lines, and arrowheads where required. In the case of mapping, this capability labels the linear feature with length and azimuth.

Batch Processing. The technique of processing an entire group (batch) of similar or related jobs or input items on a system at one time without operator interaction. Contrast with interactive graphics system.

Benchmark. The program(s) used to test, compare, and evaluate in real time the performance of various CAD/CAM systems prior to selection and purchase. A synthetic benchmark has preestablished parameters designed to exercise a set of system features and resources. A live benchmark is drawn from the prospective user's workload as a model of the entire workload.

Bill of Materials (BOM). A listing of all the subassemblies, parts, materials, and quantities required to manufacture one assembled product or part, or to build a plant. A BOM can be generated automatically on a CAD/CAM system.

Bit. The smallest unit of information that can be stored and processed by a digital computer. A bit may assume only one of two values: 0 or 1 (i.e., ON/OFF or YES/NO). Bits are organized into larger units called words for access by computer instructions.

Computers are often categorized by word size in bits, i.e., the maximum word size that can be processed as a unit during an instruction cycle (e.g., 16-bit computers or 32-bit computers). The number of bits in a word is an indication of the processing power of the system, especially for calculations or for high-precision data.

Bulk Memory. A memory device for storing a large amount of data, e.g., disk drum, or magnetic tape. It is not randomly accessible like main memory.

Byte. A sequence of adjacent bits, usually eight, sixteen or thirty-two representing a character that is operated on as a unit. Usually shorter than a word. A measure of the memory capacity of a system, or of an individual storage unit (as a 300-million-byte disk).

CAD (computer-aided design). A process which uses a computer system to assist in the creation, modification, and display of a design.

CAD/CAM (computer-aided design/computer-aided manufacturing). Refers to the integration of computers into the entire design-to-fabrication cycle of a product or plant.

CAM (computer-aided manufacturing). The use of computer and digital technology to generate manufacturing-oriented data. Data drawn from a CAD/CAM data base can assist in or control a portion or all of a manufacturing process, including numerically controlled machines, a computer-assisted parts programming, computer-assisted process planning, robotics, and programmable logic controllers. CAM can involve: production programming, manufacturing engineering, industrial engineering, facilities engineering, and reliability engineering (quality control). CAM techniques can be used to produce process plans for fabricating a complete assembly; to program robots; and to co-ordinate plant operation.

Cathode-Ray Tube (CRT). The principal component in a CAD display device. A CRT displays graphic representations of geometric entities and designs and can be of various types: storage tube, raster scan, or refresh. These tubes create images by means of a controllable beam of electrons striking a screen. The term CRT is often used to denote the entire display device. See also performance, CRT.

Central Processing Unit (CPU). The computer brain of a CAD/CAM system which controls the retrieval, decoding, and processing of information, as well as the interpretation and execution of operating instructions - the building blocks of application and other computer programs. A CPU comprises arithmetic, control, and logic elements.

Color Display. A CAD/CAM display device. Color raster-scan displays offer a variety of user-selectable, contrasting colors to make it easier to discriminate among various groups of design elements on different layers of a large, complex design. Color speeds up the recognition of specific areas and subassemblies, helps the designer interpret complex surfaces, and highlights interference problems. Color displays can be of the penetration type, in which various phosphor layers give off different colors (refresh display), or the TV-type with red, blue, and green electron guns (raster-scan display).

Command. A control signal or instruction to a CPU or graphics processor, commonly initiated by means of a menu/tablet and electronic pen or by an alphanumeric keyboard.

Compatibility. The ability of a particular hardware module or software program, code, or language to be used in a CAD/CAM system without prior modification or special interfaces. Upward compatible denotes the ability of a system to interface with new hardware or software modules or enhancements (i.e., the system vendor provides with each new module a reasonable means of transferring data, programs, and operator skills from the user's present system to the new enhancements).

Computer Graphics. A general term encompassing any discipline or activity that uses computers to generate, process and display graphic images. The essential technology of CAD/CAM systems. See also CAD.

Configuration. A particular combination of a computer, software and hardware modules, and peripherals at a single installation and interconnected in such a way as to support certain application(s).

Cursor. A visual tracking symbol, usually an underline or crosshairs, for indicating a location or entity selection on the CRT display. A text cursor indicates the alphanumeric input; a graphics cursor indicates the next geometric input. A cursor is guided by an electronic or light pen, joystick, keyboard, etc., and follows every movement of the input device.

Crosshairs. Moveable horizontal and vertical lines used to define point location on a graphic CRT. Also, graphic cursor.

Data Base. A comprehensive collection of interrelated information stored on some kind of mass data storage device, usually a disk. Generally consists of information organized into a number of fixed-format record types with logical links between associated records. Typically includes operating system instructions, standard parts libraries, completed designs and documentation, source code, graphic and application programs, as well as current user tasks in progress.

Data Tablet. A CAD/CAM input device that allows the designer to communicate with the system by placing an electronic pen or stylus on the tablet surface. There is a direct correspondence between positions on the tablet and addressable points on the display surface of the CRT. Typically used for indicating positions on the CRT, for digitizing input of drawings, or for menu selection. See also graphic tablet.

Design File. Collection of information in a CAD data base which relates to a single design project and can be directly accessed as a separate file.

Digitizer. A CAD input device consisting of a data tablet on which is mounted the drawing or design to be digitized into the system. The designer moves a puck or electronic pen to selected points on the drawing and enters co-ordinate data for lines and shapes by simply pressing down the digitize button with the puck or pen.

Dimensioning, Automatic. A CAD capability that will automatically compute and insert the dimensions of a design or drawing, or a designated section of it.

Disk (storage). A device on which large amounts of information can be stored in the data base. Synonymous with magnetic disk storage or magnetic disk memory.

Display. A CAD/CAM work station device for rapidly presenting a graphic image so that the designer can react to it, making changes interactively in real time. Usually refers to a CRT.

Dot-Matrix Plotter. A CAD peripheral device for generating graphic plots. Consists of a combination of wire nibs (styli) spaced 100 to 200 styli per inch, which place dots where needed to generate a drawing. Because of its high speed, it is typically used in electronic design applications. Accuracy and resolution are not as great as with pen plotters. Also known as electrostatic plotter.

Drum Plotter. An electromechanical pen plotter that draws an image on paper or film mounted on a rotatable drum. In this CAD peripheral device a combination of plotting-head movement and drum rotation provides the motion.

Dynamic Menuing. This feature allows a particular function or command to be initiated by touching an electronic pen to the appropriate key word displayed in the status text area on the screen.

File. A collection of related information in the system which may be accessed by a unique name. May be stored on a disk, tape, or other mass storage media.

Flatbed Plotter. A CAD/CAM peripheral device that draws an image on paper, glass, or film mounted on a flat table. The plotting head provides all the motion.

Input Devices. A variety of devices (such as data tablets or keyboard devices) that allow the user to communicate with the CAD/CAM system, for example, to pick a function from many presented, to enter text and/or numerical data, to modify the picture shown on the CRT, or to construct the desired design.

Instruction Set. (1) All the commands to which a CAD/CAM computer will respond. (2) The repertoire of functions the computer can perform.

Intelligent Work Station/Terminal. A work station in a system which can perform certain data processing functions in a stand-alone mode, independent of another computer. Contains a built-in computer, usually a microprocessor or minicomputer, and dedicated memory. See also distributed processing.

Interactive. Denotes two-way communications between a CAD/CAM system or work station and its operators. An operator can modify or terminate a program and receive feedback from the system for guidance and verification.

Interactive Graphics System (IGS) or interactive computer graphics. A CAD/CAM system in which the work stations are used interactively for computer-aided design and/or drafting, as well as for CAM, all under full operator control, and possibly also for text-processing, generation of charts and graphs, or computer-aided engineering. The designer (operator) can intervene to enter data and direct the course of any program, receiving immediate visual feedback via the CRT. Bilateral communication is provided between the system and the designer(s). Often used synonymously with CAD.

Jaggies. A CAD jargon term used to refer to straight or curved lines that appear to be jagged or saw-toothed on the CRT screen.

Layering. A method of logically organizing data in a CAD/CAM data base. Functionally different classes of data (e.g. various graphic/geometric entities) are segregated on seperate layers, each of which can be displayed individually or in any desired combination. Layering helps the designer distinguish among different kinds of data in creating a complex product such as a multilayered PC board or IC.

Learning Curve. A concept that projects the expected improvement in operator productivity over a period of time. Usually applied in the first 1 to 1 1/2 years of a new CAD/CAM facility as part of a cost-justification study, or when new operators are introduced. An accepted tool of management for predicting manpower requirements and evaluating training programs.

Literary Graphics (or parts library). A collection of standard, often-used symbols, components, shapes, or parts stored in the CAD data base as templates or building blocks to speed up future design work on the system. Generally an organization of files under a common library name.

Light Pen. A hand-held photosensitive CAD input device used on a refreshed CRT screen for identifying display elements, or for designating a location on the screen where an action is to take place.

Line Printer. A CAD/CAM peripheral device used for rapid printing of data.

Magnetic Disk. A flat circular plate with a magnetic surface on which information can be stored by selective magnetization of portions of the flat surface. Commonly used for temporary working storage during computer-aided design. See also disk.

Magnetic Tape. A tape with a magnetic surface on which information can be stored by selective polarization of portions of the surface. Commonly used in CAD/CAM for off-line storage of completed design files and other archival material.

Mainframe (computer). A large central computer facility.

Mass Storage. Auxiliary large-capacity memory for storing large amounts of data readily accessible by the computer. Commonly a disk or magnetic tape.

Memory. Any form of data storage where information can be read and written. Standard memories include random access memory and read only memory.

Megabyte. One million bytes of digital information.

Menu. A common CAD/CAM input device consisting of a checkerboard pattern of squares printed on a sheet of paper or plastic placed over a data tablet. These squares have been preprogrammed to represent a part of a command, a command, or a series of commands. Each square, when touched by an electronic pen, initiates the particular function or command indicated on that square. See also data tablet and dynamic menuing.

Microcomputer. A smaller, lower-cost equivalent of a full-scale minicomputer. Includes a microprocessor (CPU), memory, and necessary interface circuits. Consists of one or more ICs (chips) comprising a chip set.

Model, Geometric. A complete, geometrically accurate 3D or 2D representation of a shape, a part, a geographic area, a plant or any part of it, designed on a CAD system and stored in the data base. A mathematical or analytical model of a physical system used to determine the response of that system to a stimulus or load.

Program. A precise sequential set of instructions that direct a computer to perform a particular task or action, or solve a problem. A complete program includes plans for the transcription of data, coding for the computer, and plans for the absorption of the results into the system. As a verb, it means to develop a program. See also computer program.

Puck. A hand-held, manually controlled input device which allows coordinate data to be digitized into the system from a drawing placed on the data tablet or digitizer surface. A puck has a transparent window containing crosshairs.

Random-Access Memory (RAM). A main memory read/write storage unit which provides the CAD/CAM operator direct access to the stored information.

Raster Display. A CAD work-station display in which the entire CRT surface is scanned at a constant refresh rate. The bright, flicker-free image can be selectively written and erased. Also called a digital TV display.

Raster Scan (video). Currently, the dominant technology in CAD graphic displays. Similar to conventional television, it involves a line-by-line sweep across the entire CRT surface to generate the image. Raster scan features include: good brightness, accuracy, selective erase, dynamic motion capabilities, and the opportunity for unlimited color. The device can display a large amount of information without flicker, although resolution is not as good as with storage-tube displays.

Read-Only Memory (ROM). A memory which cannot be modified or reprogrammed. Typically used for control and execute programs.

Refresh (or vector refresh). A CAD display technology that involves frequent redrawing of an image displayed on the CRT to keep it bright, crisp, and clear. Refresh permits a high degree of movement in the displayed image as well as high resolution. Selective erase or editing is possible at any time without erasing and repainting the entire image. Although substantial amounts of high-speed memory are required, large, complex images may flicker.

Resolution. The smallest spacing between two display elements which will allow the elements to be distinguished visually on the CRT. The ability to define very minute detail. For example, the resolution of Computervision's IC design system is one part in 33.5 million. As applied to an electrostatic plotter, resolution means the number of dots per square inch.

Response Time. The elapsed time from initiation of an operation at a workstation to the receipt of the results at that work station. Includes transmission of data to the CPU, processing, file access, and transmission of results back to the initiating work station.

Software. The collection of executable computer programs including application programs, operating systems, and languages.

Storage. The physical repository of all information relating to products designed on a CAD/CAM system. It is typically in the form of a magnetic tape or disk. Also called memory.

System. An arrangement of CAD/CAM data processing, memory, display and plotting modules - coupled with appropriate software - to achieve specific objectives. The term CAD/CAM system implies both hardware and software. See also operating system, (a purely software term).

Tablet. An input device on which a designer can digitize coordinate data or enter commands into a CAD/CAM system by means of an electronic pen. See also data tablet.

Text File. A file stored in the system in text format which can be printed and edited on-line as required.

Track Ball. A CAD graphics input device consisting of a ball recessed into a surface. The designer can rotate it in any direction to control the position of the cursor used for entering coordinate data into the system.

Turnkey. A CAD/CAM system for which the supplier/vendor assumes total responsibility for building, installing, and testing both hardware and software, and the training of user personnel. Also loosely, a system which comes equipped with all the hardware and software required to do a specific application or applications. Usually implies a commitment by the vendor to make the system work, and to provide preventive and remedial maintenance of both hardware and software. Sometimes used interchangeably with standalone, although standalone applies more to system architecture than to terms of purchase.

View Port. A user-selected, rectangular view of a part, assembly, etc. which presents the contents of a window on the CRT. See window.

Window. A temporary, usually rectangular, bounded area on the CRT which is user-specified to include particular entities for modifications, editing, or deletion.

Wire-Frame Graphics. A computer-aided design technique for displaying a three-dimensional object on the CRT screen as a series of lines outlining its surface.

APPENDIX 2

LIST OF VENDORS

Appendix 2 List of Vendors

The top ten CAD/CAM, CAE vendors:

Computervision Canada Inc.
1725 - 27th Avenue N.E.
Calgary, Alberta T2E 7E1

IBM Canada Ltd.
10250 - 101 Street
Edmonton, Alberta T5J 3P4

IBM Canada Ltd.
Sun Life Plaza
144 - 4th Avenue S.W. Ste. 600
Calgary, Alberta T2P 3N5

INTERGRAPH SYSTEMS LTD.
3115 - 12th Street, N.E.
Calgary, Alberta T2E 7J2

CALMA COMPANY
Suite 1200, 1 Young Street
Toronto, Ontario M5E 1E5

McAuto
McDonnell Douglas Canada Ltd.
P.O. Box 6013
Toronto, Ontario L5P 1B7

Applicon
6711 Mississauga Road
Mississauga, Ontario L5N 2W3

Control Data
1855 - Minnesota Court
Mississauga, Ontario L5N 1K7

Auto-trol
Block A25 - 6120 - 2nd Street, S.E.
Calgary, Alberta T2H 2L8

Alberta vendors - micro-based systems

PPL Computer Graphics
5638 - 103A Street
Edmonton, Alberta T6H 2J5
Cascade - Turnkey Systems
Cascade - IBM PC software
Scribe software

NOMAD Computer Systems Corp.
10744 - 124 Street
Edmonton, Alberta T5M 0H1
VERSACAD - Turnkey Systems and Software

Imagineering Personal Computer Consultants Ltd.
301, 10190 - 104 Street
Edmonton, Alberta T5J 1A2
AUTOCAD, CUBICOMP - Software and Turnkey Systems

The Answer Man
14310 - 111 Avenue
Edmonton, Alberta
AUTOCAD

The Answer Man
333 - 11th Avenue S.W.
Calgary, Alberta
AUTOCAD

Computer Resources
4014 - McLeod Train, Ste. 107
Calgary, Alberta
DRAFTEC

Following is an alphabetical listing of Micro Based CAD Vendors. The main headquarters is listed for each and in most cases will be a U.S. address. If there are any Canadian subsidiaries, the main offices can be contacted for that information. All dollar amounts are stated in U.S. dollars.

Following each title is the code  . If the first dot is filled in it will indicate a turnkey package, the second dot will indicate software only and both dots will indicate the system is marketed both ways.

ACDS 7000 

ACDS Graphic Systems Inc., 100 Rue Edmonton St., Suite 232, Hull, Quebec J8Y 6N2 - Dave Strutt 819-770-9631. Turnkey system consists of a 32-bit super micro, 1.5mb RAM, 35mb disk storage (expandable) dual-screen workstation, Bit Pad digitizer, keyboard and word processing software; plotter not included. Price: $25,000 to $50,000; optional software modules: HUB - $16,000, Lattice - $8,000, DBMS - $8,000, User Extensibility Environment - $16,000. Updates: included with service and maintenance contract or billable. Training: seminars, on-site, in-house and manual.

ACDS 7000 is an interactive turnkey drafting and design system assembled around a 32-bit super microcomputer that can support up to six workstations. Four modules available for the system provide varying capabilities. Features of HUB, the two-dimensional design and drafting module, are area calculations, floor-plan generation, symbols library, bill of materials and scheduler, site plans, urban planning and road layout. The Lattice module is a three-dimensional surface modeling package with walk-thrus and hidden-line and surface removal. DEMS module is a network database management system with a query language for specs, take-offs, schedules, reports and structural analysis. User Extensibility Environment is a run-time macro generator for creating personalized applications.

ADS-II Architectural Drafting System 

Design Data Systems Corp., 5270 N. Park Place, N.E. Cedar Rapids, Iowa 52402 - F.J. Krause, 319-373-1571. For use with the HP 9836C computer workstations, HP 7580, 7585 and 7586 plotters, HP 9111A digitizer, HP 9133XV Winchester, and optional graphics printer. Price: $10,000 - includes three symbols libraries. Updates: free during first year, billable thereafter. Training: in-house, on-site, manual or telephone support.

ADS-II Architectural Drafting System is a two-dimensional drafting system with capabilities that include site plans produced from legal descriptions, topography plots created from survey data, bubble/flow diagrams, and working drawings. Added features are mirror imaging, stretch, on-screen calculator, and on-screen composition of plotter layout.

A/E CADD 200 

ECOM, 8634 West Brown Deer Rd., Milwaukee, Wisc. 53224 - Ellen Henson, 414-354-0243. For use with HP series 200 computers and peripherals. Price: from $32,300 for turnkey system; ECOM software modules $1,000. Updates: billable. Training: 8 hours of on-site training free; billable thereafter, manual, in-house.

A/E CADD 200 is a two-dimensional drafting package built around HP EGS-200 Graphics Editor enhanced with any combination of three customized modules: architectural with standard details; office planning and layout; and structural with standard details.

ARBASE 

SKOK Systems Inc., 222 Third St., Cambridge, Mass. 02142 - Steve O'Neill, 617-868-6003. For use with Artech Datastation comprising HP 9816 CPU, Pascal o/s, 750k RAM memory, 9 in. monochrome screen and keyboard; range of disk options and networking available. Price: $10,000; discounts available for multiple purchases. Updates: included with service/maintenance contract. Training: seminar, in-house, on-site and manual.

ARBASE is a fully relational database integrated to the ARPLAN software with sophisticated data entry, organizational and reporting capabilities. Usable for project management, facilities management, office and project cost control and accounting. ARBASE can be used on the Artech Designstation and lower cost Artech Datastation.

ARCADE 2 

BruningCAD, 6111 E. Skelly Dr., Tulsa, Okla. 74135 - William F. Albu, 918-663-5291. Turnkey system consists of MC 68000-based processor, 1.9mb RAM, 14.5mb Winchester hard disk, dual 3 1/2 in. floppy drives, 19 in. raster display with articulated mounting arm, 3 button optical mouse, full modular keyboard; Thermal Graphics printer and D-size plotter. Price: $49,795. Updates: offered as part of comprehensive support package for 1 per cent of system price per month. Training: on-site.

Arcade 2 is a drafting and design system incorporating such automatic features as drawing with walls, bands, and using levels or overlays. Optional software modules include AttriBase, an attributive database that incorporates an interactive spread sheet and bill-of-materials.

ARCHITECTS FRIEND - V1.1 

Team Design, 5290 North Picket Dr., Colorado Springs, Colo. 80907 - Robert L. Moore, 303-598-0663. Program operates as part of a turnkey system or with IBM PC and compatible computers running MS-DOS. Peripherals include PGS MAX12 and Color Graphics XL-19 monitors, Houston Instruments DMP-52 plotter, SAC Sonic digitizer and NEC P-3 printer. Price: from $2,895 for software; $27,995 for turnkey package. Updates: free; modem option. Training: in-house, on-site, manual, computer-aided instruction and video-training cassettes.

Architect's Friend-V1.1 is an integrated graphics-based applications package that includes project management, energy analysis, full cost and general accounting, word processing, spec writing, floor plans, elevations, renderings and development planning. Developed in concert with architects and written in "C" language for transportability. Uses a standard file management database.

Architectural Interactive Design System 

ARCAD, 445 South Figueroa St., Los Angeles, Calif. 90071 - Peter H. Martin, 213-627-1427. For use with VAX 11/780, 11/750, 11/730, 11/725. Textronix 4000-series terminals; Versatec, Calcomp and HP plotters. Price: $7,000 for one workstation; $14,000 thereafter, turnkey package available for $60,000. Updates: billable. Training: manual and telephone support.

Architectural Interactive Design System performs computerized design production drafting, providing three-dimensional solids modelling, "walk arounds" in full color, symbols and detail library, line-weight control, pattern-fill and automatic dimensioning. Sixty-day evaluation period at cost.

ARCHITECTURAL PRODUCTION DRAWINGS 

Intergraph Corporation, One Madison Industrial Park, Huntsville, Ala. 35807 - Al Kemper, 205-772-2000. A basic turnkey system consists of one computer workstation, hard printer, plotter and software. Systems are based on DEC-VAX and PDP-11 computers. Price: Turnkey package with software starts at $120,000. Updates: free with service/maintenance contract. Training: in-house, on-site implementation plan, computer-aided instruction and manual.

Architectural Production Drawings develops elevations, sections, details and reflected ceiling plans. All drawings are automatically dimensioned at the desired scale. Project specifications associated with the drawings and stored in the DMRS database (included in the basic turnkey package) are readily extracted and printed out as complete door and finish schedules.

ARMAC 

SKOK Systems Inc., 222 Third St., Cambridge, Mass. 02142 - Steve O'Neill, 617-868-6003. For use with Artech Designstation or Datastation. Price: $5,000. Updates: included with service/maintenance contract. Training: seminar, in-house, on-site and manual.

ARMAC is a macro-language system which allows the user to write special purpose graphics routines in ARPLAN. The routines are combinations of graphics primitives which may include calculations and data transfer to the ARBASE relational database product.

ARPLAN 

SKOK Systems Inc., 222 Third St., Cambridge, Mass. 02142 - Steve O'Neill, 617-868-6003. For use with Artech Designstation comprising HP 9920 CPU, Basic 3.0 o/s, 2mb RAM memory 19-in. color screen, menu tablet with stylus and keyboard; graphics processor upgrade including 1mb RAM. Price: $17,500; discounts available for multiple purchases. Updates: included with service/maintenance contract. Training: in-house, on-site, manual and seminar.

ARPLAN is a two-dimensional design and drafting system. Among capabilities are layering, colors, symbol and pattern libraries, global editing and a feature called block stretch, which permits designers to stretch and shrink elements in a schematic diagram without concern for dimensional accuracy. ARPLAN also draws the parallel lines of walls to specified thickness and automatically cuts off and seals their ends.

ARVIEW is an add-on product to ARPLAN that allows the user to define the third dimension for all items in a two-dimensional file. The resulting forms may then be viewed and evaluated as three-dimensional representations in wire-frame or as surface shaded models. With the Graphics Processor option installed in the Artech Designstation, real-time manipulation and viewing of the model is available.

ARTEC 1 

Go Fukai, P.O. Box 330040, San Francisco, Calif. 94133 - Dennis Fukai, 415-362-1424. For use with Macintosh and Lisa with optical or laser printer; requires 128k RAM; hard disk recommended. Price: $1,300/yr. license. Updates: billable. Training: on-site and computer-aided instruction.

ARTEC 1 offers interactive design decisions referenced in a pixel-based CAD system. The program demonstrates preliminary specification and graphic relationships while displaying cost feasibility parameters for immediate evaluation. Features full screen draw, memo and editing.

ARTEC 2 

Go Fukai, P.O. Box 330040, San Francisco, Calif. 94133 - Dennis Fukai, 415-362-1424. For use with Macintosh and Lisa with optical or laser printer; requires 512k RAM; hard disk recommended. Price: $1,800/yr. license. Updates: billable. Training: on-site and computer-aided instruction.

ARTEC 2 generates contract documents through refinement of initial design concepts established in Artec 1. Permits continuous interaction between cost and graphic relationships, establishing a format, for construction drawings that relate three-dimensional volumes inherent in the design. Specifications and detailing are interfaced in the printed output.

AUTOCAD 

AutoDesk, Inc., 150 Shoreline Highway, Building B, Mill Valley, Calif. 94941 - Jennifer Newman, 415-331-0356. For use with IBM PC, Victor 9000, Zenith, NEC, DEC, Eagle and Texas Instruments microcomputers; requires MS-DOS, PC-DOS or CP/M operating systems, keyboard, digitizer, touchpen or stylus, plotter or printer and 256k RAM min. Price: $1,500. Updates: billable. Training: on-site and manual.

AUTOCAD is a menu-driven two-dimensional program for producing schematics and working drawings. Users may create screen menus via ordinary text files, define parts libraries and interactively create and edit drawings of any size and scale. An optional drafting package features dimensioning, cross hatch/pattern fill, fillets, partial delete and a units-command for both dimensions and coordinates in feet and inches. AUTOCAD-to-Integraph translator permits graphics transfer between systems.

AUTOPLAN 

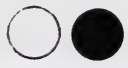
Automated Design, P.O. Box 507, Valley Forge, Pa. 19481 - Roberta C. Carnwath, 215-935-2420. For use with Commodore 8032 computer, 8050 disk drive and Western Graphtec plotter. Price: $3,500 per workstation for turnkey system; $995 for software only. Updates: free. Training: manual.

AUTOPLAN is a two-dimensional drafting system that displays inputs instantaneously on a plotter. Details, plans, layouts and text can be saved and combined with standard details, plans, overlays, title blocks, logos and dimensions previously on file.

AYCAD 

Aydin Controls, 414 Commerce Dr., Ft. Washington, Pa. 19034 - Ron Schlie, 215-542-7800. Turnkey system consists of Aydin Controls multiple microprocessor CPU, 21mb Winchester disk drive, 1.2mb floppy disk drive, 1mb main memory, 13-in. and 19-in. (color) monitors, 12-by 12-in. digitizing tablet, ASCII keyboard and software. Price: $47,500. Updates: included as part of license fee. Training: in-house, on-site.

AYCAD turnkey system is a two- and three-dimensional (wire-frame) design and drafting system for schematics, other preliminary design documents and working drawings. Also performs word processing and structural analysis.

BUILDING DESIGN SYSTEM (BDS) 

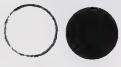
McDonnell Douglas Automation Company (McAuto), Box 516, St. Louis, Mo. 63166, Marketing Services, 800-325-1551. For use with Prime 2250, 2550, 9650, 9750, 9950; DEC-VAX Micro, 11/750, 11/780; Calcomp, HP plotters; Tektronix terminals, Tektronix hard copy units; requires 500k RAM. Available as part of turnkey package or software license. Price of turnkey system from $68,000. Updates available. Training in-house.

Building Design System (BDS) is a three-dimensional computer graphics system for designing and modeling buildings. It has been developed by architects, engineers, and planners and is meant to be used by such. BDS follows the logical sequence of architectural design from programming to schematic design, design development, and construction documentation and is fully compatible with the General Drafting System (GDS) listed below.

CAD 10 

Sumicom, Inc., 17862 E. 17th St., Tustin, Calif. 92680 - Paul Kam, 714-730-6061. Turnkey package consists of SUMICOM System 830 exclusively; uses CP/M-80 operating system and Houston Instruments DMP series plotter; System 830 has built-in, dot matrix bi-directional, correspondence-quality printer. Also features 8-color, 640 by 400 pixel screen and 10 function keys and 8 edit keys. Price: $4,590 including software. Updates: not available. Training: manual and in-house-software/hardware support.

CAD 10 program draws diagrams, schematics, floor plans and easily transposes them to paper. User can draw symbols, transcribe them into perfectly scaled drawings with editing, updating and reorganizing capabilities. Alignment grid with submenu enables design or copy of any symbol ten times the size of the actual drawing. CAD 10 utility program includes the Caduty Auxiliary Program, permitting assembly of individual symbols or entire sets of symbols.

CAD-1 

Chessel-Robocom Corporation, 111 Pheasant Run, Newtown, Pa. 18940 - Peter Kendall, 215-968-4422. For use with Apple II or Apple IIe; requires two disk drives, controller, super serial card and male-to-male RS-232-C cable; recommended plotter is HP 7470; 3-axis joystick controller supplied with software. Price: $1,095. Updates: billable. Training: manual.

CAD-1 is a menu driven two-dimensional drafting and graphics system with color capabilities and symbols libraries for producing schematics, flow charts and simple scale drawings on up to a D-size plotter. Joystick controller supplied with software is both a drawing instrument and menu-function selector. Turnkey workstation packages available.

CAD-2 

Chessel-Robocom Corporation, 111 Pheasant Run, Newtown, Pa. 18940 - Peter Kendall, 215-968-4422. For use with Apple II or Apple IIe; requires 128k RAM. Price: $1,790; includes 128k RAM board, precision controller, interface module, library disk and tutorial documentation. Updates: billable. Training: manual.

CAD-2 is a more powerful version of CAD-1, enhanced with automatic dimensioning and numerical data entry.

CADDRAFT MINDSET 

Personal CAD Systems Inc., 981 University Ave., Los Gatos, Calif. 95030 - Tereze Hanley, 800-858-6384. For use with Mindset computer, requires 256k RAM; two floppy disk drives, mouse, and HP 7470 and 7475 plotter. Price: $495 for software only; available as package with CPU and software but no plotter for $4,000. Updates: first update free, then billable. Training: seminar, in-house, on-site, manual, on-line help files.

CADDRAFT is an easy-to-use, entry-level menu-driven package for creating editing, and plotting two-dimensional designs; and data on up to seven layers. Mindset computer offers 16 colors and high-quality graphics, which may be viewed individually or in combination with other layers.

CADKEY 

Micro Control Systems, Inc., 27 Hartford Turnpike, Vernon, Conn. 06066 - Helen Charov, 203-647-0220. For use with IBM PC or compatible microcomputers; requires 384k RAM, one 320k floppy disk drive, color graphics adaptor card, graphics monitor, 2-D/3-D digitizer or mouse and a pen plotter or dot matrix printer. Price: $1,495. Updates: billable. Training: seminar, in-house, on-site, manual and computer-aided instruction.

CADKEY is an interactive two- and three-dimensional design and drafting system with primary applications that include mechanical design, detailed drafting, architectural engineering and schematics. Functions include automatic dimensioning, hidden-line removal, 3-dimensional transforms, fillets and chamfers. Command structure can be modified to resemble many larger CAD/CAM system command-formats.

CADPLAN 

Personal CAD Systems, Inc., 981 University Ave., Los Gatos, Calif. 95030 - Tereze Hanley, 800-858-6384. For use with IBM PC-XT or compatible computers, 320k RAM, 320k disk drive, 10mb hard disk drive, color monitor, IBM color graphics card, mouse or digitizer. Price: $1,900. Updates available. Training: seminar, in-house, on-site, manual, on-line help files.

CADPLAN is a two-dimensional drafting system for schematics, design development, and production drawings. Includes walls with automatic intersection detailing, automatic door and window insertion, dimensioning, database extraction, texturing, mirroring, splines, and extensive system libraries. For architecture; hvac, electrical, plumbing, and rendering. Supports high-resolution color and most peripherals.

CADVANTAGE 

Haworth, One Haworth Center, Holland, Mich. 49423 - Kris Ward, 616-392-5961. For use with IBM PC-XT with 128k RAM, color graphics adapter board, Hayes 1200b external modem, Toshiba P1340 printer, HP 7475A plotter and Mouse Systems optical mouse. Price: $19,500 for turnkey system. Updates: billable at $500 per year. Training: expenses-paid four-day seminar at Haworth Center provided with turnkey package.

CADVANTAGE is Haworth's computer-aided design and drafting software and furniture library built around a turnkey IBM PC. The system allows access to the entire Haworth product/price catalog and also offers the user color graphics, cost quotation, records management and project report capabilities. Designers have the option of drawing upon the Haworth database or creating their own database.

CASCADE I 

Cascade Graphics Development, 1000 S. Grand Ave., Santa Ana, Calif. 92705 - Ken Barney, 714-558-3316. For use with IBM PC with graphics card, Apple IIe/II+, requires two disk drives and monochrome monitor, input; joystick, koala pad or Summagraphics tablet; output. Houston Instruments DMP plotters, HP plotters, Epson, MPI printers. Price: $895 for Apple, $1,680 for IBM. Updates: billable. Training: manual.

CASCADE I computer-aided-design system performs the basic tasks found in larger systems such as lines, arcs, circles, elipses, text, zoom-in for enlarging, zoom-out for reducing, move, copy, delete, axis lock, non-axis lock, grid pick, free pick, layering, automatic dimensioning, automatic crosshatching, rotate, scale, pan and groups.

CASCADE II 

Cascade Graphics Development, 1000 S. Grand Ave., Santa Ana, Calif. 92705 - Ken Barney, 714-558-3316. Turnkey package utilizes Apple IIe with 128k RAM, 5mb hard disk, 5 1/4 in. floppy disk drive, monochrome monitor, input. Summagraphics tablet, output. DMP plotters, HP plotters, Epson and MPI printers. Price: $14,000. Updates: billable or free with service/maintenance contract. Training: manual, in-house and seminar.

CASCADE II turnkey system is designed for two-dimensional graphics production using menu-driven drawing tasks to create fundamental primitives such as lines, arcs, text and combinations of these groups. Symbols can be created or chosen from available symbols libraries, enabling quick development of drawings. The system is fully compatible with CASCADE V and CASCADE X, permitting future upgrades.

CASCADE V 

Cascade Graphics Development, 1000 S. Grand Ave., Santa Ana, Calif. 92705 - Ken Barney, 714-558-3316. Turnkey package utilizes computer with 128k RAM, 5mb hard disk, 5 1/4 in. floppy disk drive and monochrome monitor, input. Summagraphics tablet, output. DMP plotters, HP plotters, Epson and MPI printers. Price: $23,500. Updates: billable or free with service/maintenance contract. Training: manual, in-house and seminar.

CASCADE V is a menu-driven turnkey design and drafting system with five independent processors that operate such peripherals as keyboard, stylus and joystick. Zoom and pan feature enables a user to stretch, rotate and move objects. A database management system permits itemizing components in a drawing to produce a bill of materials.

CASCADE X 

Cascade Graphics Development, 1000 S. Grand Ave., Santa Ana, Calif. 92705 - Ken Barney, 714-558-3316. Turnkey system consists of computer with 128k RAM (68000 Processor), dual high-resolution monochrome monitor displays, 5mb hard disk and 5 1/4 in. floppy drives, input. Summagraphics tablet, output. HI-DMP plotters, HP plotters, Epson and MPI printers. Price: $29,850. Updates: billable or included with service/maintenance contract. Training: manual, in-house and seminar.

CASCADE X is a high-resolution (1024 by 798) design drafting system with dual monitors that allow a user to view the menu on one screen and draw on the other. Strap-on package, the Associate enables users to add text to drawings and create double-line walls and floor plans with automatic cleanup of the corners. Also permits doors and windows of specified widths to be automatically created to scale and inserted into walls.

CEADS-CADD 

Holguin, 5822 Cromo Dr., El Paso, Texas 79912 - John Wiseman, 915-581-1171. Turnkey packages are based on the following hardware: HP 1000 Models 65/66/26/27, Micro 26, Micro 27 and Micro 29; supports HP 7585 plotter, 2623 workstations and various digitizers and printers. Price: $67,000 to $138,000. Updates: included with service/maintenance contract or billable. Training: seminar, on-site and manual.

CEADS-CADD is a two-dimensional general purpose design and drafting system that can support up to 12 workstations. Software can be tailored for specific applications such as AEC, mechanical design, facilities management and others, with user-selectable parameters. Fourteen modules make up a complete system, including drawing creation, editing, plotting, digitizing, system manager, bill of materials and more (example: moving a door or window and proper wall terminations can occur automatically).

CEADS-CASC is a self-contained software product, highly complementary to CEADS-CADD. It provides macro capability, allowing the user to generate families of parts/drawings from a single command sequence and then transfer them directly to CEADS-CADD drawing workspace. The program is essentially a programming language that the user writes in to construct a command sequence to describe or draw a given geometry.

CEADS-GMS is a three-dimensional solids-modeling software product that can be integrated with Holguin's CEADS-CADD system. CEADS-GMS utilizes a command language and a versatile graphic sketching mode that will guide users in generating simple three-dimensional primitives, more complex shapes and intricate solids modeling.

CLM COGO 

CLM/Systems, Inc. 3654 Gandy Blvd., Tampa, Fla. 33611 - C.L. Miller, P.E., 813-831-7090. For use with IBM PC-XT, Sage IV, TI Professional and Wang PC; Supports HP, HI, Calcomp and Numonics plotters; compatible digitizers are HI, Calcomp and Numonics; requires 512k RAM. Price: $4,950, Turnkey package also available for $25,000 - includes 4 graphics terminals, D-size plotter, 20-in. x 20-in. digitizer and multi-mode printer. Updates: free. Training: seminar, in-house, on-site, manual and computer-aided instruction.

CLM COGO produces preliminary and final drawings for site planning, topography, grading, drainage, roads, and utilities. Generates preliminary and final cost estimates from a variety of schedules. Program options include a relational database, word processor and spreadsheet.

DESIGN BOARD 3D 

Mega CADD, Inc., 419 Second Ave. S., Seattle, Wash. 98104 - Rob Lebow, 206-623-6245. For use with IBM-PC-XT and compatibles, requires color graphics card, mathcoprocessor and mouse. Price: $750. Updates: billable. Training: manual.

Design Board 3D is a three-dimensional modelling package for the front-end conceptual and schematic design phases of an architectural/interior design/space planning project. With the software, users can create and modify designs in three dimensions, work with flat and free-form curved surfaces, design in plan and view simultaneously in perspective, remove hidden lines in one step and view and generate drawings in any orientation desirable.

DESIGN GRAPHIX 

Hamilton HGL Software, 6 Pearl Court, Allendale, N.J. 07401 - George E. Timmons, 800-631-0298. For use with DEC-VAX, PRO 350 or PDP-11. Price: complete turnkey systems from $38,000 - software only from $7,000. Updates: billable. Training: one week in-house with turnkey system, manual, on-site and computer-aided instruction for software.

Design Graphix is a turnkey two- and three-dimensional stand-alone or multi-user design and drafting system. Typical features are menu or keyboard-driven data entry, snap, grid, pan, zoom and windows, concurrent plotting and database exchange. Graphic and non-graphic files can be combined for performing item counts, take-offs, specifications and drawing notes.

DESIGN ORIENTED GRAPHICS SYSTEM 

PAFEC Engineering Consultants Inc., 5401 Kingston Pike, Suite 610, Knoxville, Tenn. 37919 - Tom Baudry, 615-584-2117. For use with most 32-bit computers including DEC-VAX, Apollo, Data General MV Series, Harris and Prime. Price: $20,000 - $30,000. Updates: included with yearly maintenance. Training: seminar, in-house, on-site and manual.

Design Oriented Graphics System (DOGS) is a two- and three-dimensional drafting system available as a turnkey system or software only. The system includes standard architectural symbols, multiline wall sections, multiple overlays. English and metric units with architectural-style dimensioning and among many other features, databse analysis capabilities for cost estimating and bill of materials.

DESIGNER I 

Orcatech, 1000 Morrison Dr., Ottawa, Ontario, K2H 8K7 - Mark Milinkovich, 613-726-1600. Turnkey system consists of an ORCA 1000 CPU computer graphics workstation with 512k RAM and a 10mb hard disk, 19-in. high-resolution monochrome or color monitor, separate text monitor, keyboard with joystick and software. Price: $38,000 CDN monochrome, $47,000 CDN color, software only: $13,000, quantity discounts for additional workstations. Updates: billable. Training: on-site, seminars and manual.

Designer I is a two-dimensional drafting sytem for engineering and architecture. Specific applications-capabilities are electrical layout, space planning, general schematics and business graphics. Turnkey system comes with a Fortran compiler and a library of 200 Fortran-callable subroutines. Optional digitizing tablet and expandable memory.

DGS-2000 

Data Automation, 10731 Treena St., Suite 106, San Diego, Calif. 92131 - Rick Hackworth 619-695-0806. For use with HP 9800- or 200-series computers; supports digitizers including HP 9111A graphics tablet, Hipad digitizer and Houston Instruments Series 7000; plotters include any HP plotter, Calcomp drum plotter or HI DMP 41/42/51 or 52; requires 187k user RAM after boot-up. Price: $1,995 for base package - $5,000 includes architectural symbols and 40 hours on-site training. Updates: billable. Training: on-site, manual and hot line ($365 per year).

DGS-2000 is a menu-driven two-dimensional design and drafting system for preliminary and working drawings. Includes database organization, high-speed zoom and pan, move, rotate, scale, mirror, layering, splining and user-created or Ansi symbols library.

DIGITRAK 

Chempro Data Sciences Corp., 507 Southampton Rd., Westfield, Mass. 01085 - Norman St. Martin 413-562-2353. For use with IBM PC-XT, color or monochrome monitors, Digitrak sonic digitizer, supports most plotters. Price: $5,470. Updates: free for first year, billable thereafter. Training: seminars, in-house, on-site, computer-aided instruction, manual and telephone support.

DIGITRAK is a design and drafting system with applications including mechanical, lighting, hvac and energy/solar. Among capabilities are axis, grid, snap with rubber band, layering, line, circle, arc, fillet, change, copy, move, text erase and plot.

DIMENSION III

Calma Company, 2901 Tasman Dr., Santa Clara, Calif. 95050 - T. Sherman, 408-748-9600. Turnkey system based on the Data General 16-bit Eclipse, DEC 32-bit VAX, or 32-bit Apollo computers. Price: costs vary depending on hardware and software configuration. Updates: billable. Training: seminar, in-house, on-site, manual and computer-aided instruction.

Dimension III is a core software system for design and drafting in architecture, engineering and construction that supports any of nearly a dozen specific application packages. These include two-dimensional architectural drafting, facilities layout, civil-site preparation and steel layout and design.

DRAWING PROCESSOR

BG Graphic Systems Inc., 824 Stetson Ave., Kent, Wash. 98031 - R.F. Bousley, 206-852-2736. For use with IBM PC, PC-XT, Eagle PC-XL Plus, Eagle 1600, Compaq, Columbia and DEC Rainbow; requires 256k RAM. Price: $995. Updates: billable. Training: manual.

Drawing Processor is a menu-driven two-dimensional drafting and technical illustration package for architects, designers, engineers and manufacturers. Edit capabilities include block move with rubberbanding (all lines move as a unit), block erase, block components (for repetitive placement), selective erasure, computer-assisted dimensioning, layering and differential scaling. External file can be output in ASCII. Optional file transfer utilities program costs $200.

ICON SERIES 2000 

Summagraphics Corporation, 777 State St. Extension, P.O. Box 781, Fairfield, Conn. 06430 - Kathy Dunn, 203-384-1344. Turnkey system consists of Data General Desktop Generation computer, 19-in. black-and-white graphic display; alpha/numeric display, fiberglass workstation and built-in 20-by-20-in. digitizing tablet; plotter and color display optional. Price: $50,000. Updates: included with service/maintenance contract. Training: seminars, in-house, on-site and manual.

ICON Series 2000 is a turnkey system/workstation that enables a user to create, preview, edit, store and recall a drawing, with text, on a graphic display. Drives many plotters for drawing output. Optional software modules are word processing, engineering/surveying, bill of materials, cost estimating/quantity take-off and a user's programmable module, which permits users to tailor the over-all system to their own needs.

IDP 

Largo Soft International, 1 Hameasfim St. (Eliahu House), Tel-Aviv, Israel 64736 - Telephone: 03-256876, Telex 35301 LARGO IL. For use with IBM PC, PC-XT and computers running MS-DOS or CP/M-86; requires 512k RAM, two 320k disk drives, graphics terminal, light pen and HP plotters. Price: $9,995. Updates: billable. Training: manual and computer-aided instruction.

IDP software performs two- and three-dimensional (wire frame) preliminary design and drafting with instant recall/change, quantities take-offs, and zooming and plotting in any scale. Other features are isometric drafting of lines and overview of structure from frontal view.

IDRAW 3 

Information Displays, Inc., 11222 LaCienega Blvd., Suite 660, Inglewood, Calif. 90304 - Nancy E. Nicoll, 213-417-5386. For use with Apollo DN 300, DN 320 or DN 550 computers with Summagraphics bit-pad and HP plotters. Price: $20,000. Updates: billable. Training: in-house and manual.

IDRAW 3 is a software-only or turnkey drafting system with more than 70 program functions available through simple menu selection. Expandable applications include mechanical and electrical engineering. Optional modules for the architectural package are a three-dimensional version ($10,000), materials-take-off ($6,000), scheduling ($6,000) and facilities management (no price information).

IGOS 

MGS Inc., 2035 S. Arlington Heights Rd., Suites 114-115, Arlington Heights, Ill. 60005 - John Scholten or Ed Hedlund, 312-437-2040. Turnkey system includes DEC-PDP-11/73 with 50- 200mb disk storage, two high-resolution screens and digitizer, drives any plotter. Price: from $45,000 for turnkey system with two screens and digitizer. Updates: available with maintenance contract. Training: in-house, on-site, manual and seminars.

IGOS is a self-contained two- and three-dimensional turnkey CADD workstation that can be interfaced with a mainframe or assembled into a multiple-user network. Primary applications are preliminary design, working drawings, space planning and facilities management. Software features include bill of materials, take-offs and a fully relational database management system.

ILLUSTRATOR: ARCHITECTURAL RENDERING DESIGN SYSTEM 

Auto-trol Technology, 12500 N. Washington St., P.O. Box 33815, Denver, Colo. 80233 - Thomas C. Curry, 303-452-4919. For use with Advanced Graphic Workstation-Apollo based; Supports HP, Calcomp or Versatec plotters, Seiko, TI and Tektronix hard copy. Price: $1,000. Updates: free. Training: seminar, in-house, on-site and manual.

Illustrator: Architectural Rendering Design System assists in the creation of presentation-quality renderings for client approval or for submittal to the appropriate commissions and agencies. The program includes a symbol library of over 70 basic figures, such as cars, trucks, people and vegetation, which can be inserted into existing plan, elevation, isometric or perspective drawings.

INTERFACE DESIGNER 3-D SERIES 

Interface Data Systems, 2990 E. LaJolla St., Anaheim, Calif. 92806 - James B. Young, 714-630-8030. For use with IBM PC, PC-XT or compatible microcomputers, uses Microsoft mouse, HP or Bausch & Lomb A-E-size plotters and Interface Micro 186 or Micro 286 monochrome or color workstations; requires 256-1024k RAM. Price: from $1,295 depending on configuration. Updates: free first year, $500 per year thereafter. Training: seminar, manual.

Interface Designer 3-D Series is a modular,upgradable two- and three-dimensional design and drafting system capable of projecting or plotting plan or two- and three-dimensional perspective views simultaneously. Drafting module has auto-dimensioning, scale, pan, zoom, and editing in two or three dimensions. Graphics generator module illustrates reaction of a structure to static or dynamic loads.

INVENTORY

Decision Graphics Inc., 11 Main St., P.O. Box 306, Southborough, Maine 01772 - John Nilsson, 617-481-4119. For use with any VAX/VMS system, any terminal, any printer. Price: $5,000 - $16,000. Updates: billable. Training: on-site, manual.

Inventory reads any PEAC (Decision Graphic's turnkey system) drawing and generates files containing all the elements in main and sub-drawings. Query function permits user to interactively search the inventory file and obtain reports on quantities for any item or for all items in a drawing. Generates bill of materials reports from inventory files.

KEYSTONE CAD GRAPHICS

Keystone Project Management Systems, 235 S. Maitland Ave., Maitland, Fla. 32751 - Stan Levine, 305-628-1932. For use with CP/M, CP/M-86, MS-DOS and PC-DOS operating systems (includes computers from Texas Instruments, DEC, IBM and Wang); CP/M requires 53k RAM, 128k for all others; turnkey hardware package provides 46mb of disk storage. Software supports high-resolution CRT, digitizer or mouse and most plotters. Price: $4,500 - $6,000 for software. Updates: billable. Training: seminar, in-house, on-site and computer-aided instruction.

Keystone CAD Graphics is a two-dimensional system for schematics. Performs design and planar drafting. Stores all entities as parametric data. Drawings may contain up to 128 layers. Displays grid points. Other features are snap mode, lettering in any size or orientation, symbols libraries, zoom and center. Software is part of a modular, stand-alone or multiple-user system with networking and database capability. Other interactive modules are project management and word processing.

MGI ARCHITECTURAL DRAFTER 

Microcomputer Graphics, Inc., 13468 Washington Blvd., Marina Del Rey, Calif. 90292 - Fred Roberts, 213-822-5258. For use with IBM and other computers running MS-DOS, peripherals include Bausch & Lomb and HP plotters (A-E); Epson printers and Mitsubishi high-resolution monitors. Price: $5,995. Updates: free for first year, billable thereafter. Training: seminar, in-house, on-site, manual and computer-aided instruction.

MGI/Architectural Drafter generates two-dimensional working drawings on IBM PC and compatibles using keyboard alone for all functionals and operations. Auto construction lines provide a short cut in developing elevations. Standard features are user-definable grids, database analysis for cost estimating and bill of materials and variable dimensioning. Drawing Manager program and symbols templates available.

MICAD 

Micro-Installations, Inc., 260 Fifth Ave., New York, N.Y. 10001 - Ira Hayes Fuchs, 212-889-6684. Turnkey system comprises a 16-bit color graphics computer (uses 8086/8087 microprocessor), D-size plotter and digitizing tablet with 12-button cursor puck. Price: $15,000 for computer system. Updates: included with service contract. Training: System price includes 20-hours of on-site training; in-house training, manual and computer-aided instruction available as well.

MICAD is a two-dimensional design and drafting system running AUTOCAD software enhanced with Graph-Facts. Graph-Facts permits attributes to be assigned to any element in a drawing and enables users to perform material-cost take-offs, space-usage projections, hvac analyses and facilities management functions.

MICROCAD 

Computer Aided Design of San Francisco, 764 Twenty-Fourth Ave., San Francisco, Calif. 94121 - Shelli Johnson, 415-387-0263. For use with IBM PC and most compatibles - 2 disk drives preferred; requires 256k RAM, a digitizer (Bausch & Lomb DT-11 or Summagraphics MM1201) and plotter (Bausch & Lomb DMP or HP 7470/7475). Price: $500 - $650. Updates: cost of postage and mailer. Training: seminar, in-house, on-site and manual.

MICROCAD is an integrated two- and three-dimensional modeling and design system that permits the development and editing of plans, elevations, isometrics and perspectives. The program has an integral electronic spreadsheet or will accept input from Visicalc files and display data as high-resolution graphs. Also calculates center of gravity and moment of inertia.

MULTI-DRAW 

Cymbol Cybernetics Corporation, 169 Colonnade Rd., Ottawa, Canada K2E 7J4 - John Davies, Director of Marketing, 613-727-1880, Telex 053 3538. Turnkey system includes Cymbol C-82 32-bit computer, 40mb hard disk, 19-in. monitor, 1mb floppy and furniture; system supports any brand-name plotter. Unbundled software can run on DEC-VAX 730 and up. Price: $20,000 for software, $39,000 for turnkey package. Updates: $400 per year includes hardware and software maintenance, free updates and consultation. Training: on-site, manual or computer-aided instruction.

Multi-Draw is a two- and three-dimensional drawing package for preliminary, finished and working drawings. Complete take-off package and symbols library. Performs interior design, space planning and facilities management as well.

PC CAD 

Houseman & Associates, Box 474, Cypress, Texas 77429 - Keith Houseman, 713-890-5160. For use with IBM PC or PC-XT, digitizers, 36" x 48" plotters; requires 128k RAM. Price: $1,450; plotting option available for $3,000. Updates: free. Training: seminar, in-house, manual or computer-aided instruction.

PC CAD is a design and drafting system that automates the design process for contouring and earthwork and permits the development of fully annotated two-dimensional site plans with 16-digit accuracy.

PC-DRAW 

Micrografx, Inc., 1701 N. Greenville, Suite 703, Richardson, Texas 75081 - Linda Curtis 214-234-1769. For use with IBM PC and compatibles with 128k RAM; requires graphics monitor, color/graphics adapter, graphics printer or plotter and two disk drives. Price: $395. Updates: billable. Training: manual and computer-aided instruction.

PC-DRAW is an interactive drawing system that enables users to create and save drawings. PC-DRAW supports any type or complexity of drawing through the use of free-hand drawing, symbols libraries and graphics functions including object scaling, rotation and placement. Supports IBM text and an alternate text (which supports multiple fonts). Multiple output formats are included. Also supports a light pen and HP plotters.

PLAN: ARCHITECTURAL DRAFTING AND DOCUMENTATION SYSTEM 

Auto-trol Technology, 12500 N. Washington St., P.O. Box 33815, Denver, Colo. 80233 - Thomas C. Curry, 303-452-4919. For use with Advanced Graphic Workstation Apollo based; supports HP, Calcomp or Versatec plotters, Seiko, TI and Tektronix hard copy. Price: $1,750. Update: free. Training: seminar, in-house, on-site and manual.

Plan: Architectural Drafting and Documentation System is a drafting and documentation system for creating architectural floor plans. Included are column grids, electrical and plumbing symbology, stairs and vertical access and drawing annotation such as text, dimensions, and general notes. An extrude function creates three-dimensional wire frames from two-dimensional views.

PLOT 10 TEKNICAD 

Tektronix, Inc., P.O. Box 1000, Wilsonville, Ore. 97070 - Andrew Davis, 503-685-3785. Software runs on Tektronix Smart Workstations or Tektronix display terminals with stand-alone graphics processor. Price: $1,600 for software; turnkey packages range from $18,000 to $35,000. Updates: free during first year; included with annual maintenance agreement thereafter. Training: seminars, in-house, on-site and manual.

PLOT 10 TEKNICAD is a menu-driven two-dimensional design and drafting system intended primarily for the creation of mechanical, electrical, facilities and structural drawings. Follows ANSI Y14 and ISO drafting standards. Other capabilities are zoom and pan, stock and user-generated symbols libraries and point, line and arc input modes.

PLOTS 

Decision Graphics Inc., 11 Main St., P.O. Box 306, Southborough, Maine 01772 - John Nilsson, 617-481-4119. For use with any VAX/VMS system; peripherals: Calcomp pen and electrostatic plotters, Tektronix ink-jet color copies and 4100 terminals. Price: $5,000 - $16,000. Updates: billable. Training: on-site and manual.

PLOTS is a set of four programs that provide complete, sophisticated graphic output including overlays, pen controls, composite assembly and scaling. Graphic output can be directed to a screen for viewing or to a plotter for hard copy.

PRO DRAFT 

Bausch & Lomb, P.O. Box 14547, Austin, Texas 78761 - Jerry Norman, 512-837-8952. Turnkey system consists of minicomputer control unit/Winchester disk drive, Raster display, detached keyboard, menu tablet and single-sheet plotter for up to D-size drawings; digitizers optional. Price: $29,900. Updates: included with maintenance agreement. Training: in-house, on-site and manual.

PRO DRAFT is a turnkey package for two-dimensional design and drafting that can be customized for any of five applications: residential, commercial, light commercial, renovation and hvac. The system features drafting libraries, layering and a one-touch command control for scaling, rotation, border, drawing-size and line weight. A bill-of-materials module is available for $2,000.

RANDMICAS 

The Rand Group, 17430 Campbell Rd., Suite 14, Dallas, Texas 75252 - Ross Wheeler, 214-661-0124. For use with IBM PC-XT, 43xx, 33xx; DEC-VAX; Sun Systems; Mascomp; Pixel; Wang 2200; requires 10mb hard disc minimum, graphic CRT and plotter. Price: $7,000 and up. Updates: free for first year, billable thereafter.

RANDMICAS is an interactive finite element analysis and design system built around a full-relational database. Included in the system are modules for steel design, concrete design, static analysis and dynamic analysis. The system also has full two- and three-dimensional graphics with a comprehensive analysis post processing system. RANDMICAS interfaces directly to other CAD/D systems.

RUCAPS 

GMW Computers, Inc., North America, 1417 4th Ave., Seattle, Wash. 98101 - Thomas G. Phillips, 206-467-0660. For use with any Prime 32-bit virtual memory computers or DEC-PDP-11 minicomputers (Europe only); Imlac, Tektronix, Sigma and VT100 displays; Calcomp 900, 1000, HP 7500, Benson-Varian or Versatec plotters. Price: Software is available separately or as part of a complete turnkey system. Updates: two upgrade enhancements per year free. Training: seminars, in-house, on-site and manual.

RUCAPS is a three-dimensional building modeling system that produces schematics to working drawings from a single three-dimensional model. Changes made to the model updates all drawings. Optional Imager module performs simulations with full color, texture and shading. RUCAPS also performs engineering analyses, interference checking, quantities take-offs and cost-estimating.

SCULPTURED SURFACES 

Intergraph Corporation, One Madison Industrial Park, Huntsville, Ala. 35807 - Al Kemper, 205-772-2000. A basic turnkey system consists of one computer workstation, hard printer, plotter and software. Systems are based on DEC-VAX and PDP-11 computers. Price: Turnkey package with software starts at $120,000. Updates: free with service/maintenance contract. Training: in-house, on-site implementation plan, computer-aided instruction and manual.

Sculptured Surfaces supports the precise mathematical definition of complex surfaces. Structures such as spiral staircases or domed and vaulted ceilings can be defined with the precision necessary for engineering purposes.

SIGMA III 

Sigma Design, Inc., 7306 S. Alton Way, Englewood, Colo. 80112 - Vicki Morris-Hart, 303-773-0666. Turnkey system consists of an M68000-based 16/32-bit microprocessor, 1mb processor memory (min.), 30mb mass disk storage (min.), monochrome or color monitor, choice of input devices, cabinet, workstation furniture, and software. Price: from $90,000. Updates: billable. Training: seminars and in-house.

SIGMA III is a two- and three-dimensional design and drafting system with software applications for programming through working drawings and space planning/facilities management. Upgradable memory permits large workstation networks.

SITE ENGINEERING

Computervision Corporation, 100 Crosby Dr., Bedford, Mass. 01730 - Ben Smith, 617-275-1800. Software is available only as part of a turnkey package which incorporates Computervision CDS 4000. Updates: billable or included with maintenance contract. Training: in-house, manual and computer-aided instruction.

Site Engineering provides capability to convert conventional survey input or a tracing of a predrawn plan into a digitally modeled representation of the site. Using digital terrain modeling techniques, profile, cross-section, and alignment drawings can be created. Also, earthwork calculations can be determined. Requires General Mapping software package.

SYNTHAVISION

Mathematical Applications Group Inc., 3 Westchester Plaza, Elmsford, N.Y. 10523 - Rick Betts, 914-592-4646. For use with IBM 4300 and 3000 series, DEC-VAX and Apollo; requires 1mb RAM and 2mb disk storage. Price: $30,000 to $125,000. Updates: available with maintenance contract. Training: in-house, on-site and computer-aided instruction.

Synthavision offers three-dimensional solids modeling to construct and analyze any object. Complete hidden line removal. Color-shaded pictures with or without shadows. Menu has 18 primitives. Software interfaces with CADAM package to generate engineering drawings from the solid-model database. IGES interface.

TECHNIQUE NO. 9 SERIES 

Microlight-Technique Architectural Software, 4438 Valencia Ave., North Vancouver, British Columbia V7N 4B1 - John W. Whalen, 604-980-5353 or 604-926-7808. For use with all IBM, IBM-compatibles and Tandy 2000. Supports most input and output devices. E-size drawings via Calcomp 965 plotter; other plotters: HP, Bausch & Lomb. Price: from $3,500 CDN. Updates: free during first year; billable thereafter. Training: seminar, in-house, on-site, manual and computer-aided instruction.

Technique No. 9 Series generates two- or three-dimensional sketches, schematics and working drawings. Among features are full primitives generation, element or block erasure, data manipulation mode, color layer separation and details libraries. Data from the graphics package can be used for take-offs, inventories, scheduling or other user-defined options.

3-D MODELING 

Intergraph Corporation, One Madison Industrial Park, Huntsville, Ala. 35807 - Al Kemper, 205-772-2000. A basic turnkey system consists of one computer workstation, hard printer, plotter and software. Systems are based on DEC-VAX and PDP-11 computers. Price: Turnkey package with software starts at $120,000. Updates: free with service/maintenance contract. Training: in-house, on-site implementation plan, computer-aided instruction and manual.

3-D Modeling package allows the architect to quickly produce and test several alternative design solutions visually, replacing the task of drawing renderings by hand. Designs can be viewed in perspective from any angle, and presented to a client as fully shaded, color-filled models. Colors and shadows can be readily changed, and a structure presented as it would appear under different lighting conditions or with different finishes.

3D/CAD 

Archon Software, 218 West Main St., Charlottesville, Va. 22901 - Stuart G. Burgh, 804-295-2600. For use with, IBM PC, NEC or Gigatek monitor, Mouse Systems mouse, supports Houston Instruments digitizers and plotters; requires 256k RAM. Price $950. Updates: free. Training: seminar, manual.

3D/CAD creates three-dimensional models interactively using a mouse, digitizer or keyboard input. Rotates objects in three-dimensional perspective. Employs macro-object definition to create libraries of three-dimensional shapes. Hidden line removal and plane clipping soon available. Interfaces with CAD/2D to extrude any two-dimensional drawing into a three-dimensional form.

3DESIGN/3 

Tritek Vision Systems, 4710 University Way, N.E., Suite 1512, P.O. Box C56789, Seattle, Wash. 98105 - Kris Nelson, 206-632-2125. For use with IBM PC and compatibles; requires IBM or Halo-supported color graphics board, 196k RAM, two 320kb disk drives; peripherals include digitizer, mouse, dot matrix printers and plotter. Price: $1,200. Updates: free for first six months, nominal fee thereafter. Training: manual and tutorials.

3DESIGN/3 features advanced editing that allows users to create complex objects and then rotate, scale and move them and remove their hidden lines. 3DESIGN/3's two-dimensional drafting package includes auto-dimensioning, window and overlay commands, text and crosshatching. Optional conversion program permits interface to AUTOCAD. A Solidshade option color-fills and shades with a variable light source.

TOUCH'N DRAW 

Arrigoni Technology, Inc., 14127 Capri Dr., Los Gatos, Calif. 95030 - David Arrigoni, 408-370-1400. Turnkey system consists of MC68000 CPU, 1.5mb RAM, 33mb disk storage, 8 RS-232 ports, "Touch Control Station" and display module with 1280 x 1024 8-color 19-in. monitor. Price: $77,000 with D-size plotter. Updates: cost varies depending on complexity of update. Training: seminar, in-house, on-site, manual and computer-aided instruction.

TOUCH'N DRAW is a turnkey architectural design and production drawing system for small-to-medium-size firms that includes grids, symbols libraries, layering, dimensioning and take-offs as part of the base package. Optional programs are interior design, facilities management and plumbing.

2D/CAD 

Archon Software, 218 Main St., Charlottesville, Va. 22901 - Stuart G. Burgh, 804-925-2600. For use with: IBM PC, NEC or Gigatek monitor, Mouse Systems mouse; supports Houston Instruments digitizers and plotters; requires 256k RAM. Price: $1,950. Updates: free. Training: seminar, manual.

2D/CAD is a two-dimensional design and drafting system that creates drawings using a mouse, digitizer pad, or the keyboard. User-defined template libraries may be quickly created, filed and recalled to the screen for use. Selectable grids, multiple drawing levels and bi-directional zoom are standard features. Drawings are easily plotted at any time.

TWODEE

Decision Graphics Inc., 11 Main St., P.O. Box 306, Southborough, Main 01772 - John Nilsson, 617-481-4119. For use with any VAX/VMS system; peripherals: W4109 or W4115 graphic workstation. Price: $5,000 - $16,000. Updates: billable. Training: on-site, manual.

TWODEE is a general purpose design and drafting program aimed primarily at facilities planning but used also for architectural design/drafting and electrical and hvac drafting. TWODEE can fetch, store, zoom, pan, draw, add symbols, calculate, move, rotate, mirror, dimension, etc. High precision database allows work at any scale and automatic metric conversion.

ACDS 7000

ACDS Graphic Systems Inc., 100 Rue Edmonton St., Suite 232, Hull, Quebec J8Y 6N2 - Dave Strutt, 819-770-9631. Turnkey system consists of 32-bit super micro, 1.5mb RAM, 35mb disk storage (expandable) dual-screen workstation, Bit Pad digitizer, keyboard and word processing software plotter not included. Price: $25,000 to $50,000; optional software modules: HUB-$16,000, Lattice-$8,000, DBMS-$8,000, User Extensibility Environment-$16,000. Updates: included with service and maintenance contract or billable. Training: seminars, on-site, in-house and manual.

ACDS 7000 is an interactive turnkey drafting and design system assembled around a 32-bit super-microcomputer that can support up to six workstations. Four modules available for the system provide varying capabilities. Features of HUB, the two-dimensional design and drafting module, are area calculations, floor-plan generation, symbols library, bill of materials and scheduler, site plans, urban planning and road layout. The Lattice module is a three-dimensional surface modeling package with walk-thrus and hidden-line and surface removal. DBMS module is a network database management system with a query language for specs, take-offs, schedules, reports and structural analysis. User Extensibility Environment is a run-time macro generator for creating personalized applications.

APPENDIX 3

PUBLICATIONS

Appendix 3 Publications

Computer Graphics Today
475 Park Avenue South
New York, N.Y. 10016

Computer Graphics World
1714 Atlantic Avenue, Suite 220
Long Beach, CA 94133

Mini-Micro Systems
Reed Holdings, Inc.
221 Columbus Avenue
Boston, MA 02116

CIPS Review
Canadia Information Processing Society
243 College St., 5th Floor
Toronto, Ontario M5T 2Y1

Computek
Suite 202, 518 Beatty Street
Vancouver, B.C. V6B 2L4

The Anderson Report
Anderson Publishing Co.
4525 - E Industrial St., Ste. 4L
Simi Valley, CA 93063

Datamation
875 Third Avenue
New York, N.Y. 10022

Design Graphics World
390 Fifth Ave.
New York, N.Y. 10018

Software News
5 Kane Industrial Dr.
Hudson, MA 01749

CAD/CAM Products and Services in Canada
Department of Industry, Trade and Commerce
235 Queen Street
Ottawa, Ontario Canada K1A 0H5

Bute
P.O. Box 328
Hancock, NH 03449

CAD/CAM, CAE: Survey, Review and Buyers' Guide

$368 for a one-year subscription, Daratech, Inc., 16 Myrtle Avenue, P.O. Box 410, Cambridge, MA 02238 (telephone 617/354-2339).

Daratech's new survey reviews and analyzes the CAD/CAM, CAE industry and contains detailed information on 114 vendors and 236 systems. With more than 50,000 items of information in 620 pages, the guide serves as a comprehensive source of data for prospective CAD/CAM, CAE users, marketing executives, consultants, product designers, investors, and others who need a ready reference to the CAD/CAM, CAE industry. For each company there is a listing of products, services, and markets served, a company background briefing, current sales data, a breakdown of sales and installations in mechanical, architectural, civil, PCB/IC, technical documentation, and educational markets, a workforce profile and list of key executives, and sections detailing R&D, marketing, and manufacturing resources. In-depth product descriptions include over 430 items of information about each company's product line including prices, hardware and software specifications, and a profile of field service, customer support, education, and user in progress, marketing strategies, acquisitions, joint ventures, and new corporate directions. A supplementary section tracks new start-ups, their products, markets, business plans, key personnel, and venture financing. And for the industry as a whole, there are charts of market share, market segments, market share within segment, market penetration, price fluctuations, and vendor and industry growth.

APPENDIX 4

RECENT ARTICLES

Appendix 4 Recent Articles

CAD/CAM Workstation Trends, Edward L. Busick
Computer Graphics World, April 1984

Trends in a Fiercely Competitive Marketplace, Marlene Brown
Computer Graphics World, April 1984

Buying CAD/CAM Graphics, Charles M. Foundyller
American Machinist July 1981

Making a Start in CAD
ENGINEERING, MATERIALS AND DESIGN 1982

- March - The Hardware
- April - The Software
- May - Matching System of Application
- June - Organizing the Office Routine
- July - Linking With Production
- August - Getting Started

Computer-aided Design - Significant
CAD power is coming for desktop microcomputers - Rik Jadrnicek
Bute Publications Inc.

CAD Increases Effectiveness - Ken Mark
Canadian Building, March 1984

Choosing A Turnkey CAD System - Eric Teicholz
DATAMATION

Computer Aided Design Report July, 1983

Computer Aided Design - Systems
Evaluation and Selection Richard F. Barrett
Tappi Press September 1980